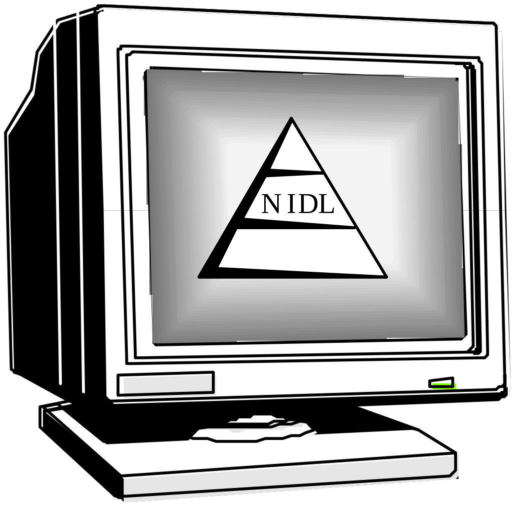

NIDL evaluated the thin, large screen, flat panel Pioneer 50 inch plasma display panel (PDP) to determine its usefulness to the display of images that are of interest to imagery analysts and GI specialists. As NIDL's ratings show, the Pioneer PDP-502MX is not going to be useful as the primary imagery analysis display on an IEC workstation. It fails many of the IEC requirements so we rate it "F" for IEC workstation monoscopic and stereo applications. Rather, its usefulness comes from its large, 50 inch diagonal size and its high pixel count for a PDP, up to 1280 x 768 pixels in the 16:9 and 1024 x 768 pixels in the 4:3 format, that could make it appropriate for group conference discussions. The Pioneer PDP-502MX has a relatively good gray scale capability; it can display 245 of 256 differences in input levels for a 7.94 bit depth. Its linearity surpasses that we have measured for CRT monitors, and comes about because of its precisely formed pixel structure. This pixel structure, like in LCD monitors, can have several non-operating pixels. It has a very high (exceeds 60% over the entire screen) and a very uniform 1-pixel-on/1-pixel-off contrast modulation for both the horizontal and vertical directions. The PDP can have a maximum luminance up to 40 fL for a small patch of white, and a minimum luminance of 0.2 fL. For full screen white, its luminance is 18 fL, limited by internal circuitry to minimize panel heat generation and its luminance is more uniform than a CRT monitor. The reflectivity and viewing angle are about the same as for a CRT monitor. It has a capability to do stereo imaging at 43 Hz per eye, which is on the borderline of visible flicker, and its dynamic range in stereo is good. The extinction ratio is poor, and is probably limited by the long persistence of the green phosphor. Most who have seen the Pioneer PDP-502MX would love to have one, at least for football games. The price is about $18,000.

Evaluation of the Pioneer PDP-502MX 4 x 3 Aspect Ratio, 50 inch Diagonal Color Plasma Display Panel

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Abstract

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Number of Pages
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CONTENTS

NIDL IEC Monitor Certification Report

The Pioneer PDP-502MX Plasma Display Panel

FINAL GRADES
Monoscopic Mode: F
Stereoscopic Mode: F

A = Substantially exceeds IEC Requirements; B = Meets IEC Requirements; C = Nearly meets IEC Requirements; F = Fails to meet IEC Requirements in a substantial way.

NIDL evaluated the thin, large screen, flat panel Pioneer 50 inch plasma display panel (PDP) to determine its usefulness to the display of images that are of interest to imagery analysts and GI specialists. As NIDL's ratings show, the Pioneer PDP-502MX is not going to be useful as the primary imagery analysis display on an IEC workstation. It fails many of the IEC requirements so we rate it "F" for IEC workstation monoscopic and stereo applications. Rather, its usefulness comes from its large, 50 inch diagonal size and its high pixel count for a PDP, up to 1280 x 768 pixels in the 16:9 and 1024 x 768 pixels in the 4:3 format, that could make it appropriate for group conference discussions. The Pioneer PDP-502MX has a relatively good gray scale capability; it can display 245 of 256 differences in input levels for a 7.94 bit depth. Its linearity surpasses that we have measured for CRT monitors, and comes about because of its precisely formed pixel structure. This pixel structure, like in LCD monitors, can have several non-operating pixels. It has a very high (exceeds 60% over the entire screen) and a very uniform 1-pixel-on/1-pixel-off contrast modulation for both the horizontal and vertical directions. The PDP can have a maximum luminance up to 40 fL for a small patch of white, and a minimum luminance of 0.2 fL. For full screen white, its luminance is 18 fL, limited by internal circuitry to minimize panel heat generation and its luminance is more uniform than a CRT monitor. The reflectivity and the viewing angle are about the same as for a CRT monitor. It has a capability to do stereo imaging at 43 Hz per eye, which is on the borderline of visible flicker, and its dynamic range in stereo is good. The extinction ratio is poor, and is probably limited by the long persistence of the green phosphor. Most who have seen the Pioneer PDP-502MX would love to have one, at least for football games. The price is about $18,000.

Evaluation Datasheet
Pioneer PDP-502MX Plasma Display Panel Monitor

Mode	IEC Requirement	Measured Performance	Compliance
MONOSCOPIC			
Addressability	1024 x 1024 min.	1024 x 768 *	Fail
Dynamic Range	24.7dB	19.2 dB	Fail
Luminance (Lmin)	0.1 fL ± 4% min.	0.210 fL	Fail
Luminance (Lmax)	30 fL, min	17.6 fL, full screen 40.1 fL 20% of screen size	Fail
Uniformity (Lmax)	20% max.	4.4%	Pass
Halation	3.5% max.	6.62% ± 0.3	Fail
Color Temp	6500 to 9300 K	6513	Pass
Reflectance	Not specified	5.14%	N/A
Bit Depth	8-bit± 5 counts	7.94 effective bits	Fail
Step Response	No visible ringing	Smearing	Fail
Uniformity (Chromaticity)	0.010 delta u'v' max. ± 0.005 delta u'v'	0.006 delta u'v'	Pass
Pixel Aspect Ratio	Square H = V± 6%	21.58 H x 20.32 V (mils) H = V+ 6.2%	Fail
Screen Size, viewable diagonal	17.5 to 24 inches ± 2 mm	42 inches as tested 50 inches maximum	Fail
Cm, Zone A, 7.6"	25% min.	63%	Pass
Cm, Zone A, 20.7"	25% min.	62%	Pass
Cm, Zone B	20% min.	62%	Pass
Pixel Density	72 ppi min.	30 H x 32 V ppi	Fail
Moiré, phosphor-to-pixel spacing	1.0 max	1.0	Pass
Straightness	0.5% max ± 0.05 mm	0.05%	Pass
Linearity	1.0% max ± 0.05 mm	0.04%	Pass
Jitter	2 ± 2 mils max.	0.74 mils	Pass
Swim, Drift	5 ± 2 mils max.	0.65 mils	Pass
Warm-up time, Lmin to +/- 50%	30 mins. Max ± 0.5 minute	<1.0 mins.	Pass
Warm-up time, Lmin to +/- 10%	60 mins. Max ± 0.5 minute	<1.0 min.	Pass
Refresh	72 ±1 Hz min. 60 ±1 Hz absolute min.	Set to 75Hz	Pass
STEREOSCOPIC			
Addressability	1024 x 1024 min.	1024 x 768 interlaced 1024 x 384 per eye	Fail
Lmin	0.1 fL	0.21 fL	Fail
Lmax	6 fL min ± 4%	2.26 fL	Fail
Dynamic range	17.7 dB min	20.3 dB	Pass
Uniformity (Chromaticity)	0.02 delta u'v' max ± 0.005 delta u'v'	0.007 delta u'v'	Pass
Refresh rate	60 Hz per eye, min	43 Hz per eye	Fail
Extinction Ratio	15:1 min	1.6:1	Fail

* As tested in 4:3 mode. Native addressability is 1280 x 768 pixels in 16:9 mode.

Section I INTRODUCTION

The National Information Display Laboratory (NIDL) was established in 1990 to bring together technology providers - commercial and academic leaders in advanced display hardware, softcopy information processing tools, and information collaboration and communications techniques - with government users. The Sarnoff Corporation in Princeton, New Jersey, a world research leader in high-definition digital TV, advanced displays, computing and electronics, hosts the NIDL.

The present study evaluates a production unit of the Pioneer PDP-502MX Plasma Display Panel. This report is intended for both technical users, such as system integrators, monitor designers, and monitor evaluators, and non-technical users, such as image analysts, software developers, or other users unfamiliar with detailed monitor technology.

The IEC requirements, procedures and calibrations used in the measurements are detailed in the following:

- *NIDL Publication No. 0201099-091*, *Request for Evaluation Monitors for the National Imagery & Mapping Agency (NIMA) Integrated Exploitation Capability (IEC)*, August 25, 1999.

Two companion documents that describe how the measurements are made are available from the NIDL and the Defense Technology Information Center at http://www.dtic.mil:

- *NIDL Publication No. 171795-036 Display Monitor Measurement Methods under Discussion by EIA (Electronic Industries Association) Committee JT-20 Part 1: Monochrome CRT Monitor Performance Draft Version 2.0. (ADA353605)*

- *NIDL Publication No. 171795-037 Display Monitor Measurement Methods under Discussion by EIA (Electronic Industries Association) Committee JT-20 Part 2: Color CRT Monitor Performance Draft Version 2.0. (ADA341357)*

Other procedures are found in a recently approved standard available from the Video Electronics Standards Association (VESA) at http://www.vesa.org:

- *VESA Flat Panel Display Measurements Standard, Version 1.0, May 15, 1998.*

The IEC workstation provides the capability to display image and other geospatial data on either monochrome or color monitors, or a combination of both. Either of these monitors may be required to support stereoscopic viewing. Selection and configuration of these monitors will be made in accordance with mission needs for each site. NIMA users will select from monitors included on the NIMA-approved Certified Monitor List compiled by the NIDL. The color and monochrome, monoscopic and stereoscopic, monitor requirements are listed in the Evaluation Datasheet.

I.1 The Pioneer PDP-502MX Plasma Display Panel

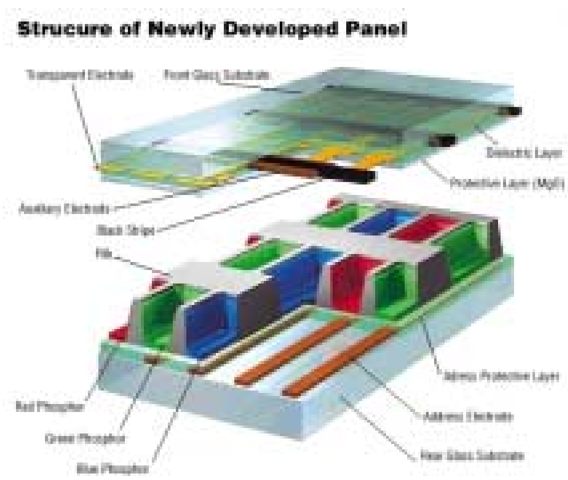
Pioneer's Specifications

According to Pioneer, the specifications for the Pioneer PDP-502MX Plasma Display Panel are:

TYPE	**PDP**	256 gray scale, 16.7 million colors
	Pixels	1280 (Horizontal.) x 768 (Vertical.)
	Pixel Pitch	0.858mm (Hor/RGB trio) x 0.808mm (Ver)
	Display Area	50" diagonal viewable area
	Aspect Ratio	4:3 and 16:9
	Viewing Angle	< 160 degrees horizontal, < 160 degrees vertical
VIDEO INPUT	**Standards**	Composite, Y/C & S-Video, RGBHV, Analog RGB 3.58 NTSC, PAL, SECAM, 4.43 NTSC, SDTV, HDTV, VESA DDC 1/2B
	Compatibility	PC, Mac®, 640 x 400 up to 1600 x 1280
	Frequency	$F_{horizontal}$ is 24.8-91.1kHz, $F_{vertical}$ is 56-85Hz, and 35.5 and 46.4 kHz, 43Hz interlace
AUDIO	**Speakers**	Two 12-watt (optional on sides, adds 11 lbs. 14 oz.)
	Amplifier	2W+2W Stereo
CONNECTORS	**Video**	BNC, Mini DIN 4 pin, Mini D-sub 15 pin, BNC (x5)
	Audio	2 pin jacks for audio in, Stereo mini jack for audio in, stereo mini jack for audio out
	Controls	RS-232C D-sub, 9-pin, In/Out Mini-DIN, 6 pin; In/Out Monaural mini-jack (x2)
POWER	**Input**	100-120VAC 50/60Hz
	Consumption	470W, Standby: 0.6 W
USER CONTROLS	**Side Panel**	Standby/On, Input, Menu, Set, Size, Display
	Remote	Standby/On, Input, Menu, Adjust, Set, Size, Muting, Volume, Display
	Picture Mode	Contrast, Bright, Color, Tint, Sharp, R Level, G Level, B Level
	Screen Mode	H-Position, V-Position, V-Size, Clock Frequency, Clock Phase
DIMENSIONS	**External**	1218mm (W) x 714mm (H) x 98mm (D) (47 $^{31}/_{32}$" x 28 $^{1}/_{8}$" x 3 $^{7}/_{8}$")
WEIGHT	**Net** **With Stand**	40.3Kg. (88.77 lbs.) 41.0Kg. (90.44 lbs.)
OPERATING RANGE	**Temperature** **Pressure** **Humidity**	0 to 40° C, (32 to 104° F) 0.8 to 1.1 atmospheres 20% to 80%
PRICE	**US**	$19,995

Additional Information Supplied by Manufacturer

- **Pioneer PDP-502MX Flat Screen Plasma Display Panel (PDP).** Large-screen PDP units boast ultra-slim dimensions, are surprisingly light in weight and deliver superb picture quality -- a combination of features that open up a host of opportunities in the visual presentation field, especially in the current HDTV/DVD era. Pioneer's next-generation PDP technology has established itself as a core element in all kinds of public display and visual communications systems. The PDP-502MX with its further improved picture quality and durability represents a major triumph for Pioneer, which has continued to lead the industry in developing and mass producing PDPs.



- **Newly Developed Panel Pushes the Previous Limits of Illumination Efficiency**. New True Matrix imaging technology makes on-screen images brighter than ever. Pioneer’s newly developed Encased Cell Structure ensures superior illumination efficiency by increasing phosphor surface area and eliminating light leakage from the neighboring above and below cells, thereby improving clarity in the vertical direction. In addition, this arrangement increases the amount of light produced resulting in brighter on-screen images.
- **Black Stripes Greatly Improve Contrast, especially in Bright Locations**. The new black stripes on the panel's non-luminous front section reduce the amount of external light reflected off the screen surface to effectively double the on-screen image contrast when the display is used in bright locations. Thanks to this innovation, viewers can enjoy sharp pictures, even under bright ambient lighting conditions, with no reduction in black contrast.
- **Improved Blue Phosphor Makes On-Screen Whites Even Whiter**. Pioneer’s new plasma display achieves more brilliant white reproduction thanks to the employment of an improved blue phosphor that features an improved illumination efficiency balance. The color temperature can be set by changing the color balance controls. * Our new phosphor development brings enhanced white reproduction and sharper contrast to every image.

*These values have individually adjusted high and low levels. Once adjusted, color balance settings can be set into one of two color memories for each type of input. All of these adjustments can be done via a wireless remote or RS-232C control.

I.2. Initial Monitor Set Up

Reference: Request for Evaluation Monitors, NIDL Pub. 0201099-091, Section 5, p 5.

All measurements will be made with the display commanded through a laboratory grade programmable test pattern generator. The system will be operated in at least a 24 bit mode (as opposed to a lesser or pseudo-color mode) for color and at least 8 bits for monochrome. As a first step, refresh rate should be measured and verified to be at least 72 Hz. The screen should then be commanded to full addressability and Lmin set to 0.1 fL. Lmax should be measured at screen center with color temperature between D65 and D93 allowable and any operator adjustment of gain allowable. If a value >35fL is not achieved (>30 fL for color), addressability should be lowered. For a nominal 1600 by 1200 addressability, addressability should be lowered to 1280 by 1024 or to 1024 by 1024. For a nominal 2048 by 2560 addressability, addressabilities of 1200 x 1600 and 1024 x 1024 can be evaluated if the desired Lmax is not achieved at full addressability.

I.3. Equipment

Reference: Monochrome CRT Monitor Performance, Draft Version 2.0 Section 2.0, page 3.

The procedures described in this report should be carried out in a darkened environment such that the stray luminance diffusely reflected by the screen in the absence of electron-beam excitation is less than 0.003 cd/m^2 (1mfL).

Instruments used in these measurements included:

- Quantum Data 8701 400 MHz programmable test pattern signal generator
- Quantum Data 903 250 MHz programmable test pattern signal generator
- Photo Research SpectraScan PR-650 spectroradiometer
- Photo Research SpectraScan PR-704 spectroradiometer
- Minolta LS-100 Photometer
- Minolta CA-100 Colorimeter
- Graseby S370 Illuminance Meter
- Microvision SuperSpot 100 Display Characterization System which included OM-1 optic module (Two Dimensional photodiode linear array device, projected element size at screen set to 1.3 mils with photopic filter) and Spotseeker 4-Axis Positioner
  Microvision SuperSpot 220 with LCD Goniometer

Stereoscopic-mode measurements were attempted using the following commercially-available stereo products:

- StereoGraphics CE-3 CrystalEyes 3 eyewear and the ENT infrared emitter.

Section II PHOTOMETRIC MEASUREMENTS

II.1. Dynamic range and Screen Reflectance

References: *Request for Evaluation Monitors, NIDL Pub. 0201099-091, Section 5.6, p 6.*

VESA Flat Panel Display Measurements Standard, Version 1.0, May 15, 199, Section 308-1.

Full screen white-to-black dynamic range in a dark room in 1024 x 768 format is 19.2 dB limited by the inability to reduce Lmin below 0.21 fL and the inability to increase Lmax beyond 17.6 fL.

Objective: Measure the photometric output (luminance vs. input command level) at Lmax and Lmin in both dark room and illuminated ambient conditions.

Equipment: Photometer, Integrating Hemisphere Light Source or equivalent

Procedure: Luminance at center of screen is measured for input counts of 0 and Max Count. Test targets are full screen (flat fields) where full screen is defined addressability. Set Lmin to 0.1 fL. For color monitors, set color temperature between D_{65} to D_{93}. Measure Lmax.

This procedure applies when intended ambient light level measured at the display is 2fc or less. For conditions of higher ambient light level, Lmin and Lmax should be measured at some nominal intended ambient light level (e.g., 18-20 fc for normal office lighting with no shielding). This requires use of a remote spot photometer following procedures outlined in reference 2, paragraph 308-2. This will at best be only an approximation since specular reflections will not be captured. A Lmin > 0.1 fL may be required to meet grayscale visibility requirements.

According to the VESA directed hemispherical reflectance (DHR) measurement method, total combined reflections due to specular, haze and diffuse components of reflection arising from uniform diffuse illumination are simultaneously quantified as a fraction of the reflectance of a perfect white diffuse reflector using the set up depicted in figure II.1-1. Total reflectance was calculated from measured luminances reflected by the screen (display turned off) when uniformly illuminated by an integrating hemisphere simulated using a polystyrene icebox. Luminance is measured using a spot photometer with 1° measurement field and an illuminance sensor as depicted in Figure II.1-1. The measured values and calculated reflectances are given in Table II.1-1.

Data: Define dynamic range by: DR=10log(Lmax/Lmin)

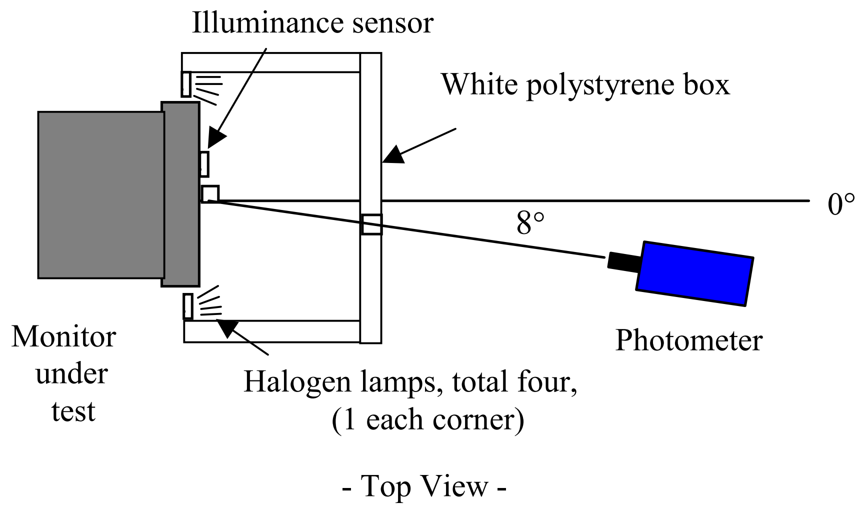


Figure II.1-1. Test setup according to VESA FPDM procedures for measuring total reflectance of screen.

Table II.1-1. Directed Hemispherical Reflectance of Faceplate

VESA ambient contrast illuminance source (polystyrene box)

Ambient Illuminance	20.0 fc
Reflected Luminance	1.03 fL
Faceplate Reflectance	5.14 %

Ambient dynamic ranges of full screen white-to-black given in Table II.1-2 were computed for various levels of diffuse ambient lighting using the measured value for DHR and the darkroom dynamic range measurements. Full screen white-to-black dynamic range is 19.2 dB in a dark room (the absolute threshold for IEC is 22 dB) and drops further when viewed in diffuse ambient illumination.

Table II.1-2.Dynamic Range in Dark and Illuminated Rooms

Effect of ambient lighting on dynamic range is calculated by multiplying the measured display faceplate reflectivity times the ambient illumination measured at the screen in foot candles added to the minimum screen luminance, Lmin, where Lmin = 0.21 fL.

Ambient Illumination	**Dynamic Range**
0 fc (Dark Room)	19.2 dB
1 fc	18.3 dB
2 fc	17.5 dB
3 fc	16.9 dB
4 fc	16.3 dB
5 fc	15.8 dB
6 fc	15.4 dB
7 fc	15.0 dB
8 fc	14.6 dB
9 fc	14.3 dB
10 fc	14.0 dB

II.2. Maximum Luminance (Lmax)

References: *Request for Evaluation Monitors, NIDL Pub. 0201099-091, Section 5.2, p 6.*

The highest luminance for full screen at Lmax was 17.6 fL measured at screen center in 1024 x 768 format. The luminance of smaller white targets was much greater than full screen luminance. Luminances as high as 40.1 fL were measured for small white patches that were reduced to only 20% of the image area.

Objective: Measure the maximum output display luminance.

Equipment: Photometer

Procedure: See dynamic range. Use the value of Lmax defined for the Dynamic Range measurement.

Data: The maximum output display luminance, Lmax, and associated CIE x, y chromaticity coordinates (CIE 1976) were measured using a hand-held colorimeter (Minolta CA-100). The correlated color temperature (CCT) computed from the measured CIE x, y chromaticity coordinates was within range specified by IEC (6500K and 9300K).

Table II.2-1. Maximum Luminance and Color of Full Screen White

Color and luminance (in fL) for Full screen at 100% Lmax taken at screen center.

Format	CCT	CIE x	CIE y	Luminance
1024 x 768	6513	0.312	0.333	17.6

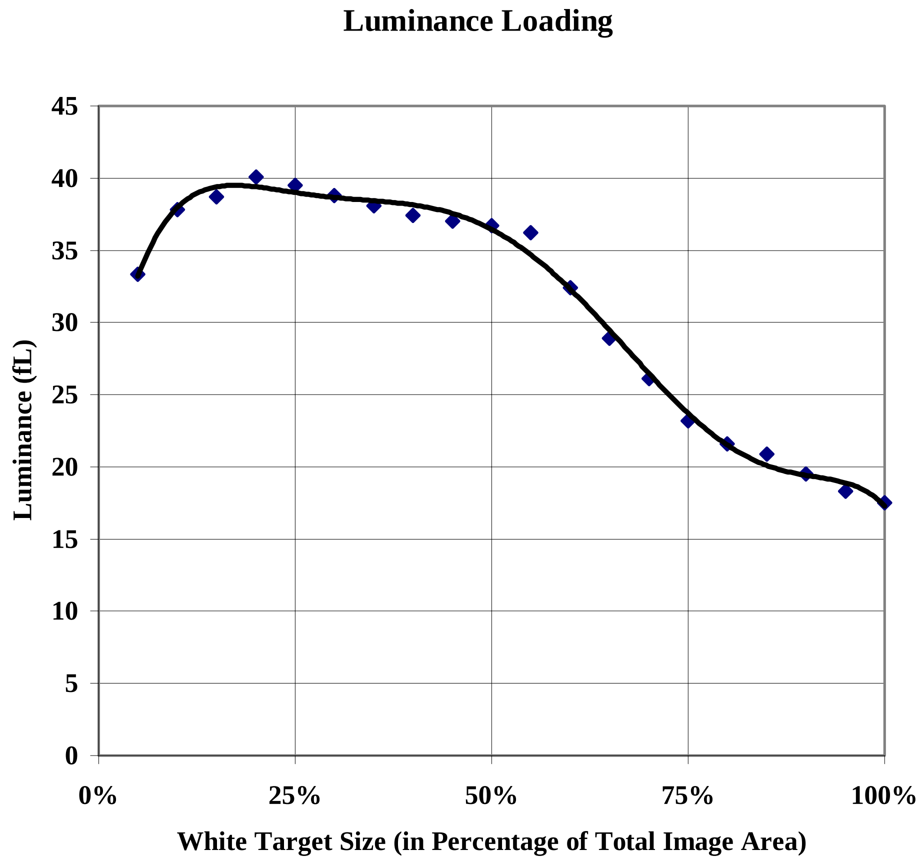


Figure II.2-1. The luminance of white varies inversely with the target size. The IEC luminance requirement is for full screen.

II.3. Luminance (Lmax) and Color Uniformity

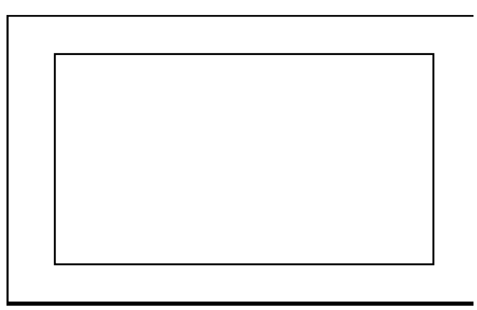
Reference: Monochrome CRT Monitor Performance, Draft Version 2.0, Section 4.4, p. 28.

Maximum luminance (Lmax) varied by up to 4.4% across the screen. Chromaticity variations were less than 0.006 delta u'v' units.

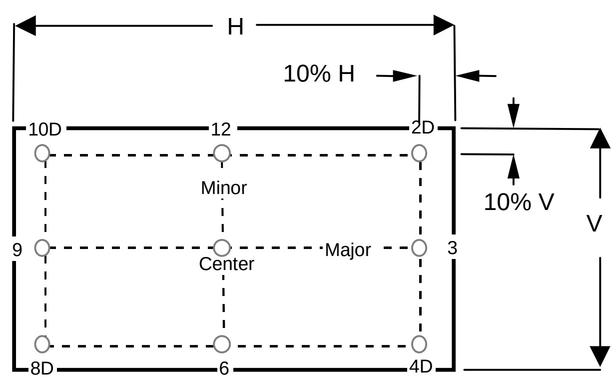
Objective: Measure the variability of luminance and chromaticity coordinates of the white point at 100% Lmax only and as a function of spatial position. Variability of luminance impacts the total number of discriminable gray steps.

Equipment:
- Video generator
- Photometer
- Spectroradiometer or Colorimeter

Test Pattern: Full screen flat field with visible edges at L_{min} as shown in Figure II.3-1.



Full Screen Flat Field test pattern.
Figure II.3-1



Nine screen test locations.
Figure II.3-2

Procedure: Investigate the temporal variation of luminance and the white point as a function of intensity by displaying a full flat field shown in Figure II.3-1 for video input count levels corresponding L_{max}. Measure the luminance and C.I.E. color coordinates at center screen.

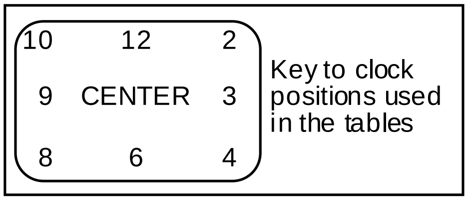
Investigate the temporal variation of luminance and the white point as a function of spatial position by repeating these measurements at each of the locations depicted in Figure II.3-2. Define color uniformity in terms of $\Delta u'v'$.

Data: Tabulate the luminance and 1931 C.I.E. chromaticity coordinates (x, y) or correlated color temperature of the white point at each of the nine locations depicted in Figure II.3-2. Additionally, note the location of any additional points that are measured along with the corresponding luminance values.

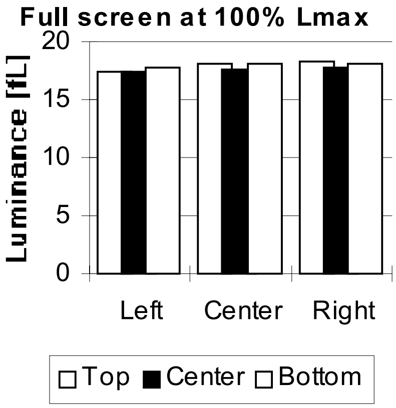
Table II.3-1.Spatial Uniformity of Luminance and Color
Color and luminance (in fL) for Full screen taken at nine screen positions.

1024 x 768

POSITION	CCT	CIE x	CIE y	L, fL
center	6513	0.312	0.333	17.6
2	6420	0.314	0.331	18.2
3	6413	0.314	0.332	17.8
4	6273	0.317	0.329	18.1
6	6460	0.313	0.333	18.1
8	6338	0.316	0.327	17.8
9	6535	0.312	0.330	17.5
10	6338	0.316	0.327	17.4
12	6407	0.314	0.333	18.1



1024 x 768



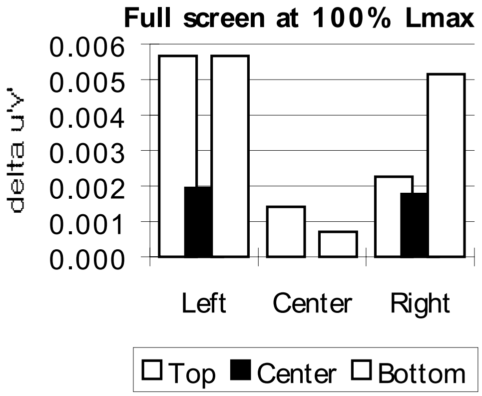


Fig.II.3-3. Spatial Uniformity of Luminance and Chromaticity.
(Delta u'v' of 0.004 is just visible.)

II.4. Halation

Reference: Monochrome CRT Monitor Performance, Draft Version 2.0 Section 4.6, page 48.

Halation was 6.62 % +/- 0.5% on a small black patch surrounded by a large full white area.

Objective: Measure the contribution of halation to contrast degradation. Halation is a phenomenon in which the luminance of a given region of the screen is increased by contributions from surrounding areas caused by light scattering within the phosphor layer and internal reflections inside the glass faceplate. The mechanisms that give rise to halation, and its detailed non-monotonic dependence on the distance along the screen between the source of illumination and the region being measured have been described by E. B. Gindele and S.L. Shaffer. The measurements specified below determine the percentage of light that is piped into the dark areas as a function of the extent of the surrounding light areas.

Equipment:
- Photometer
- Video generator

Test Pattern:

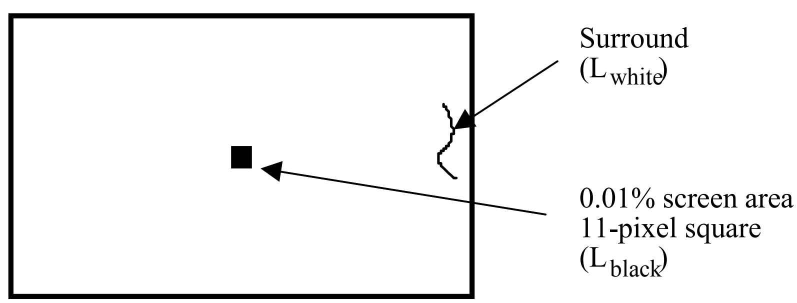


Figure II.4-1 *Test pattern for measuring halation.*

Procedure: Note: The halation measurements require changing the setting of the BRIGHTNESS control and will perturb the values of L_{max} and L_{min} that are established during the initial monitor set-up. The halation measurements should therefore be made either first, before the monitor setup, or last, after all other photometric measurements have been completed.

Determine halation by measuring the luminance of a small square displayed at L_{black} (essentially zero) and at L_{white} when surrounded by a much larger square displayed at L_{white} (approximately 75% L_{max}).

Establish L_{black} by setting the display to cutoff. To set the display to cut-off, display a flat field using video input count level zero, and use a photometer to monitor the luminance at center screen. Vary the BRIGHTNESS control until the CRT beam is visually cut off, and confirm that the corresponding luminance (L_{stray}) is essentially equal to zero. Fine tune the BRIGHTNESS control such that

CRT beam is just on the verge of being cut off. These measurements should be made with a photometer that is sensitive at low light levels (below L_{min} of the display). Make no further adjustments or changes to the BRIGHTNESS control or the photometer measurement field.

Next, decrease the video-input level to display a measured full-screen luminance of 75% L_{max} measured at screen center. Record this luminance (L_{white}).

The test target used in the halation measurements is a black (L_{black}) square patch of width equal to 0.01% of the area of addressable screen, the interior square as shown in Figure II.4-1. The interior square patch is enclosed in a white (L_{white}) background encompassing the remaining area of the image. The exterior surround will be displayed at 75% L_{max} using the input count level for L_{white} as determined above. The interior square will be displayed at input digital count level zero.

Care must be taken during the luminance measurement to ensure that the photometer's measurement field is less than one-half the size of the interior square and is accurately positioned not to extend beyond the boundary of the interior square. The photometer should be checked for light scattering or lens flare effects which allow light from the surround to enter the photosensor. A black card with aperture equal to the measurement field (one-half the size of the interior black square) may be used to shield the photometer from the white exterior square while making measurements in the interior black square.

Analysis: Compute the percent halation for each test target configuration. Percent halation is defined as:

$$\%\ \text{Halation} = L_{black} \ / \ (L_{white} - L_{black}) \ \times 100$$

Where, L_{black}= measured luminance of interior square displayed at L_{black} using input count level zero,

L_{white}= measured luminance of interior square displayed at L_{white} using input count level determined to produce a full screen luminance of 75% L_{max} .

Data: Table II.4-1 contains measured values of L_{black}, L_{white} and percentage halation.

Table II.4-1 Halation for 1024 x 768 Addressability

	Reported Values	Range for 4% uncertainty
Lblack	0.89 fL ± 4%	0.85 fL to 0.92 fL
Lwhite	13.43 fL ± 4%	12.88 fL to 13.98 fL
Halation	6.62% ± 0.5%	6.10 % to 7.18%

II.5. Color Temperature

Reference: Monochrome CRT Monitor Performance, Draft Version 2.0 Section 5.4, page 22.

The CCT of the measured white point lies within the boundaries accepted by IEC.

Objective: Insure measured screen white of a color monitor has a correlated color temperature (CCT) between 6500K and 9300K.

Equipment: Colorimeter

Procedure: Command screen to Lmax. Measure u'v' chromaticity coordinates (CIE 1976).

Data: Coordinates of screen white should be within 0.01 Δu'v' of the corresponding CIE daylight, which is defined as follows: If the measured screen white has a CCT between 6500 and 9300 K, the corresponding daylight has the same CCT as the screen white. If the measured CCT is greater than 9300 K, the corresponding daylight is D93. If the measured CCT is less than 6500 K, the corresponding daylight is D65. The following equations were used to compute Δu'v' values listed in table II.5.1:

1. Compute the correlated color temperature (CCT) associated with (x,y) by the VESA/McCamy formula: CCT = 437 n^3 + 3601 n^2 + 6831 n + 5517, where n = (x-0.3320)/(0.1858 - y). [This is on p. 227 of the FPDM standard]

2. If CCT < 6500, replace CCT by 6500. If CCT > 9300, replace CCT by 9300.

4. Use formulas 5(3.3.4) and 6(3.3.4) in Wyszecki and Stiles (pp.145-146 second edition) to compute the point (xd,yd) associated with CCT.
   - First, define u = 1000/CCT.
   - If CCT < 7000, then xd = -4.6070 u^3 + 2.9678 u^2 + 0.09911 u +
   - 0.244063.
   - If CCT > 7000, then xd = -2.0064 u^3 + 1.9018 u^2 + 0.24748 u +
   - 0.237040.
   - In either case, yd = -3.000 xd^2 + 2.870 xd -0.275.

5. Convert (x,y) and (xd,yd) to u'v' coordinates:
   - (u',v') = (4x,9y)/(3 + 12y - 2x)
   - (u'd,v'd) = (4xd,9yd)/(3 + 12yd - 2xd)

6. Evaluate delta-u'v' between (u,v) and (ud,vd):
   - delta-u'v' = sqrt[(u' - u'd)^2 + (v' - v'd)^2].

7. If delta-u'v' is greater than 0.01, display fails the test. Otherwise it passes the test.

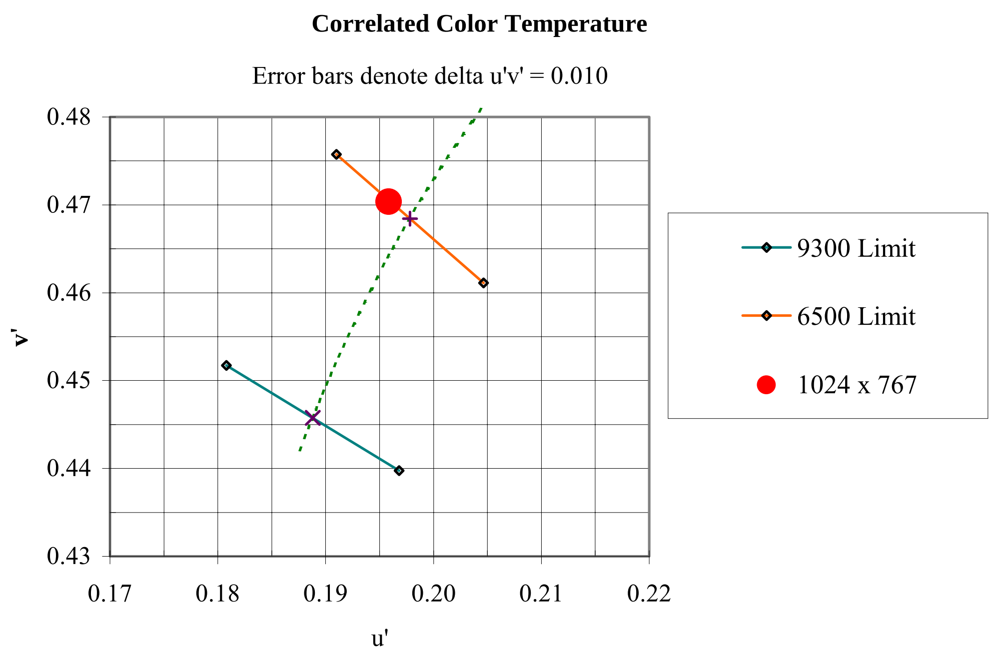


Figure II.5-1 *The CCT of the measured white point is within the boundaries required by IEC.*

Table II.5-1 Delta u'v' Distances between measured white points and CIE coordinate values from D_{65} to D_{93}.

	1024 x 768
CIE x	0.312
CIE y	0.333
CIE u'	0.196
CIE v'	0.470
CCT	6513
delta u'v'	0.003

II.6. Bit Depth

Reference: Request for Evaluation Monitors, NIDL Pub. 0201099-091, Section 5.6, p 6.

Positive increases in luminance were measured for 245 of the 256 input levels for 7.94 effective bits of gray scale. 223 of 256 input levels differed by at least 1 JND of luminance. Black level clipping was observed for levels 000 through 003. White level saturation was observed for levels 245 through 255.

Objective: Measure the number of bits of data that can be displayed as a function of the DAC and display software.

Equipment: Photometer

Test targets: Targets are n four inch patches with command levels of all commandable levels; e.g., 256 for 8 bit display. Background is commanded to 0.5* ((0.7 *P)+0.3*n) where P = patch command level, n = number of command levels.

Procedure: Measure patch center for all patches with Lmin and Lmax as defined previously. Count number of monotonically increasing luminance levels. Use the NEMA/DICOM model to define discriminable luminance differences. For color displays, measure white values.

Data: Define bit depth by $\log_2$ (number of discrete luminance levels)

The number of bits of data that can be displayed as a function of the input signal voltage level were verified through measurements of the luminance of white test targets displayed using a Quantum Data 8701 test pattern generator and a Minolta CA-100 colorimeter. Targets are n four-inch patches with command levels of all commandable levels; e.g., 256 for 8 bit display. Background is commanded to 0.5* ((0.7 *P)+0.3*n) where P = patch command level, n = number of command levels. The NEMA/DICOM model was used to define discriminable luminance differences in JNDs.

Figure II.6-1 shows the System Tonal Transfer curve at center screen as a function of input counts. The data for each of the 256 levels are listed in Tables II.6-1 and II.6-2.

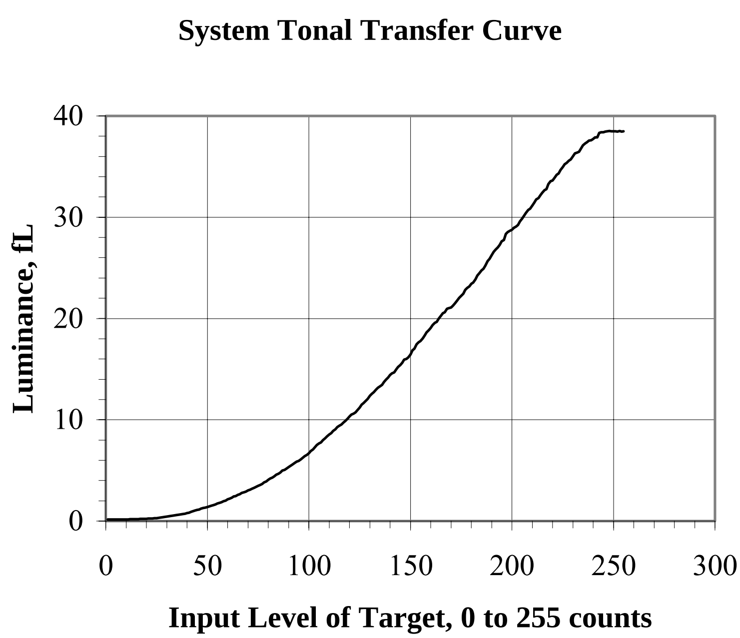


Figure II.6-1. System Tonal Transfer at center screen as a function of input counts.

Table II.6-1. System Tonal Transfer at center screen as a function of input counts. Target levels 000 to 127.

Background	Target	L, fL	Diff, fL	Diff, JND	Background	Target	L, fL	Diff, fL	Diff, JND
38	0	0.154	0.000	0	61	64	2.463	0.047	2
39	1	0.154	0.000	0	61	65	2.592	0.129	4
39	2	0.154	0.000	0	62	66	2.646	0.054	2
39	3	0.154	0.000	0	62	67	2.784	0.138	4
40	4	0.155	0.001	0	62	68	2.836	0.052	2
40	5	0.156	0.001	0	63	69	2.912	0.076	2
41	6	0.156	0.000	0	63	70	3.044	0.132	4
41	7	0.157	0.001	0	63	71	3.097	0.053	2
41	8	0.158	0.001	1	64	72	3.196	0.099	2
42	9	0.160	0.002	0	64	73	3.275	0.079	3
42	10	0.162	0.002	0	64	74	3.364	0.089	2
42	11	0.168	0.006	2	65	75	3.488	0.124	3
43	12	0.180	0.012	2	65	76	3.569	0.081	3
43	13	0.186	0.006	1	65	77	3.666	0.097	2
43	14	0.189	0.003	1	66	78	3.813	0.147	4
44	15	0.193	0.004	0	66	79	3.928	0.115	3
44	16	0.201	0.008	2	66	80	4.074	0.146	3
44	17	0.208	0.007	1	67	81	4.192	0.118	3
45	18	0.216	0.008	1	67	82	4.302	0.110	2
45	19	0.224	0.008	2	67	83	4.419	0.117	3
45	20	0.231	0.007	1	68	84	4.585	0.166	4
46	21	0.243	0.012	2	68	85	4.676	0.091	1
46	22	0.252	0.009	1	69	86	4.797	0.121	3
46	23	0.258	0.006	1	69	87	4.976	0.179	4
47	24	0.274	0.016	2	69	88	5.055	0.079	1
47	25	0.299	0.025	4	70	89	5.186	0.131	3
48	26	0.319	0.020	3	70	90	5.338	0.152	3
48	27	0.342	0.023	3	70	91	5.456	0.118	2
48	28	0.388	0.046	5	71	92	5.595	0.139	3
49	29	0.413	0.025	3	71	93	5.747	0.152	2
49	30	0.439	0.026	3	71	94	5.864	0.117	2
49	31	0.469	0.030	3	72	95	5.936	0.072	2
50	32	0.501	0.032	4	72	96	6.091	0.155	2
50	33	0.527	0.026	2	72	97	6.258	0.167	3
50	34	0.555	0.028	3	73	98	6.414	0.156	3
51	35	0.603	0.048	4	73	99	6.546	0.132	2
51	36	0.627	0.024	2	73	100	6.692	0.146	2
51	37	0.653	0.026	3	74	101	6.926	0.234	4
52	38	0.689	0.036	3	74	102	7.081	0.155	2
52	39	0.735	0.046	3	74	103	7.288	0.207	4
52	40	0.779	0.044	4	75	104	7.526	0.238	3
53	41	0.836	0.057	4	75	105	7.672	0.146	2
53	42	0.904	0.068	5	76	106	7.776	0.104	2
53	43	0.972	0.068	4	76	107	7.982	0.206	3
54	44	1.046	0.074	5	76	108	8.172	0.190	2
54	45	1.091	0.045	3	77	109	8.382	0.210	3
55	46	1.151	0.060	3	77	110	8.546	0.164	2
55	47	1.223	0.072	4	77	111	8.684	0.138	2
55	48	1.296	0.073	4	78	112	8.892	0.208	3
56	49	1.341	0.045	3	78	113	9.048	0.156	2
56	50	1.398	0.057	3	78	114	9.274	0.226	2
56	51	1.464	0.066	3	79	115	9.393	0.119	2
57	52	1.519	0.055	3	79	116	9.524	0.131	1
57	53	1.587	0.068	3	79	117	9.712	0.188	3
57	54	1.657	0.070	3	80	118	9.894	0.182	2
58	55	1.723	0.066	3	80	119	10.100	0.206	2
58	56	1.794	0.071	3	80	120	10.320	0.220	3
58	57	1.877	0.083	4	81	121	10.510	0.190	2
59	58	1.965	0.088	3	81	122	10.620	0.110	1
59	59	2.022	0.057	3	81	123	10.740	0.120	1
59	60	2.156	0.134	5	82	124	10.960	0.220	3
60	61	2.211	0.055	2	82	125	11.220	0.260	3
60	62	2.297	0.086	3	83	126	11.480	0.260	2
60	63	2.416	0.119	4	83	127	11.640	0.160	2

Table II.6-2. System Tonal Transfer at center screen as a function of input counts
Target levels 128 to 255.

Background	Target	L, fL	Diff, fL	Diff, JND
83	128	11.860	0.220	2
84	129	12.070	0.210	2
84	130	12.360	0.290	3
84	131	12.550	0.190	2
85	132	12.710	0.160	1
85	133	12.980	0.270	3
85	134	13.180	0.200	2
86	135	13.280	0.100	1
86	136	13.450	0.170	1
86	137	13.720	0.270	3
87	138	13.960	0.240	2
87	139	14.160	0.200	1
87	140	14.440	0.280	3
88	141	14.580	0.140	1
88	142	14.690	0.110	1
88	143	14.960	0.270	2
89	144	15.220	0.260	2
89	145	15.420	0.200	2
90	146	15.620	0.200	2
90	147	15.940	0.320	2
90	148	16.010	0.070	1
91	149	16.150	0.140	1
91	150	16.460	0.310	2
91	151	16.870	0.410	3
92	152	17.030	0.160	1
92	153	17.460	0.430	3
92	154	17.660	0.200	2
93	155	17.760	0.100	1
93	156	18.020	0.260	1
93	157	18.320	0.300	3
94	158	18.620	0.300	2
94	159	18.860	0.240	1
94	160	19.060	0.200	2
95	161	19.360	0.300	2
95	162	19.560	0.200	1
95	163	19.670	0.110	1
96	164	19.980	0.310	2
96	165	20.280	0.300	1
97	166	20.520	0.240	2
97	167	20.630	0.110	1
97	168	20.970	0.340	2
98	169	21.040	0.070	0
98	170	21.080	0.040	0
98	171	21.280	0.200	2
99	172	21.490	0.210	1
99	173	21.780	0.290	2
99	174	22.050	0.270	1
100	175	22.240	0.190	1
100	176	22.460	0.220	2
100	177	22.840	0.380	2
101	178	23.020	0.180	1
101	179	23.160	0.140	1
101	180	23.440	0.280	1
102	181	23.560	0.120	1
102	182	23.870	0.310	2
102	183	24.240	0.370	2
103	184	24.460	0.220	1
103	185	24.740	0.280	1
104	186	24.920	0.180	1
104	187	25.220	0.300	2
104	188	25.680	0.460	2
105	189	25.880	0.200	1
105	190	26.260	0.380	2
105	191	26.570	0.310	2

Background	Target	L, fL	Diff, fL	Diff, JND
106	192	26.80	0.23	1
106	193	27.04	0.24	1
106	194	27.28	0.24	1
107	195	27.64	0.36	2
107	196	27.76	0.12	1
107	197	28.34	0.58	2
108	198	28.54	0.20	1
108	199	28.66	0.12	1
108	200	28.76	0.10	0
109	201	28.96	0.20	1
109	202	29.08	0.12	1
109	203	29.24	0.16	1
110	204	29.58	0.34	1
110	205	29.87	0.29	1
111	206	30.16	0.29	2
111	207	30.42	0.26	1
111	208	30.72	0.30	1
112	209	30.86	0.14	1
112	210	31.16	0.30	1
112	211	31.44	0.28	1
113	212	31.76	0.32	2
113	213	31.88	0.12	0
113	214	32.16	0.28	1
114	215	32.43	0.27	1
114	216	32.66	0.23	1
114	217	32.78	0.12	1
115	218	33.27	0.49	2
115	219	33.56	0.29	1
115	220	33.62	0.06	0
116	221	33.86	0.24	1
116	222	34.18	0.32	2
116	223	34.32	0.14	0
117	224	34.68	0.36	2
117	225	34.94	0.26	1
118	226	35.23	0.29	1
118	227	35.37	0.14	0
118	228	35.58	0.21	1
119	229	35.72	0.14	1
119	230	36.02	0.30	1
119	231	36.30	0.28	1
120	232	36.36	0.06	0
120	233	36.45	0.09	0
120	234	36.77	0.32	2
121	235	37.09	0.32	1
121	236	37.30	0.21	1
121	237	37.42	0.12	0
122	238	37.56	0.14	1
122	239	37.60	0.04	0
122	240	37.72	0.12	0
123	241	37.88	0.16	1
123	242	37.90	0.02	0
123	243	38.32	0.42	1
124	244	38.40	0.08	1
124	245	38.40	0.00	0
125	246	38.44	0.04	0
125	247	38.50	0.06	0
125	248	38.52	0.02	0
126	249	38.47	-0.05	0
126	250	38.48	0.01	0
126	251	38.47	-0.01	0
127	252	38.44	-0.03	0
127	253	38.51	0.07	0
127	254	38.44	-0.07	0
128	255	38.47	0.03	0

II.8. Luminance Step Response

Reference: Request for Evaluation Monitors, NIDL Pub. 0201099-091, Section 5.8, p 7.

Video artifacts in the form of smearing were observed. Abrupt luminance variations of 1% were measured.

Objective: Determine the presence of artifacts caused by undershoot or overshoot.

Equipment: Test targets, SMPTE Test Pattern RP-133-1991, 2-D CCD array

Procedure: Display a center box 15% of screen size at input count levels corresponding to 25%, 50%, 75%, and 100% of Lmax with a surround of count level 0. Repeat using SMPTE Test pattern

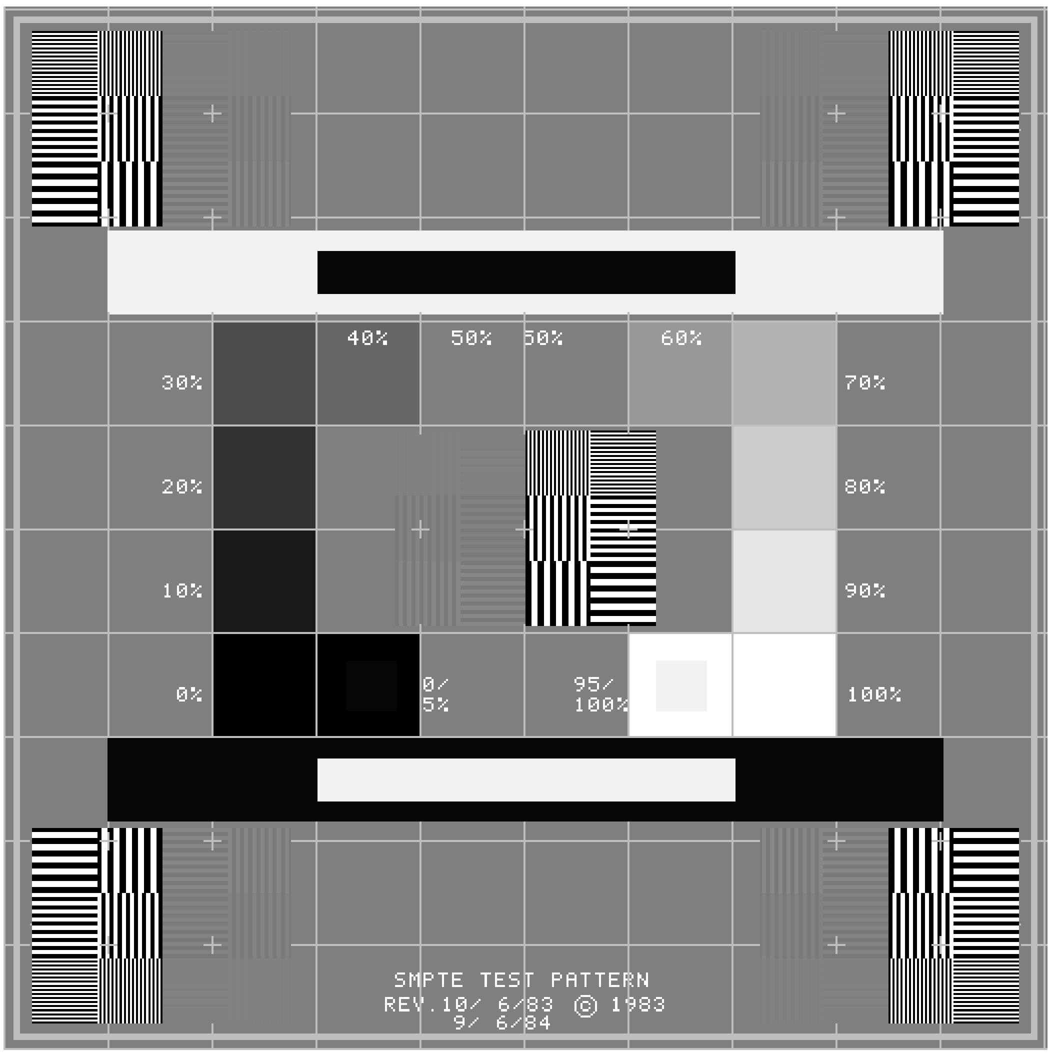


Figure II.8-1. SMPTE Test Pattern.

Data: Define pass by absence of noticeable ringing, undershoot, overshoot, or streaking.

The test pattern shown in Figure II.8-1 was used in the visual evaluation of the monitor. This test pattern is defined in SMPTE Recommended Practice RP-133-1986 published by the Society of Motion Picture and Television Engineers (SMPTE) for medical imaging applications. Referring to the large white-in-black and black-in-white horizontal bars contained in the test pattern, RP133-1986, paragraph 2.7 states " These areas of maximum contrast facilitate detection of mid-band streaking (poor low-frequency response), video amplifier ringing or overshoot, deflection interference, and halo." Video artifacts in the form of smearing were observed in the Pioneer PDP-502MX Plasma Display Panel.

Another test pattern available on the Quantum Data 8701 400 MHz programmable test pattern generator was displayed to further examine and quantify video artifacts. The test pattern consists of black horizontal bars each 12 pixels in height (approximately $^3/_8$ inch) extending across the central portion of the screen as shown in Figure II.8-2. Each black bar is surrounded by white. The black bar displayed within a white surround introduces abrupt variations in video duty cycle and challenges the display's ability to regulate luminance over a range of loading conditions. Nonuniformities on luminance of the white surround occurred depending on the presence of the black bar. For example, luminance of the white surround measured to the left and right of the black bar is approximately 1% greater compared to the luminance above and below the black bar. This small luminance difference appears as a discontinuity in the white surround and easily visible.

Table II.8-1. Luminance Non-Uniformity of White with Black Bar

Left Side Luminance of White		Right Side Luminance of White	
Above black bar	20.34 fL	Above black bar	20.79 fL
To the left of black bar	20.50 fL	To the right of black bar	21.03 fL
Below black bar	20.30 fL	Below black bar	20.82 fL
Nonuniformity	**0.87%**	**Nonuniformity**	**1.06%**

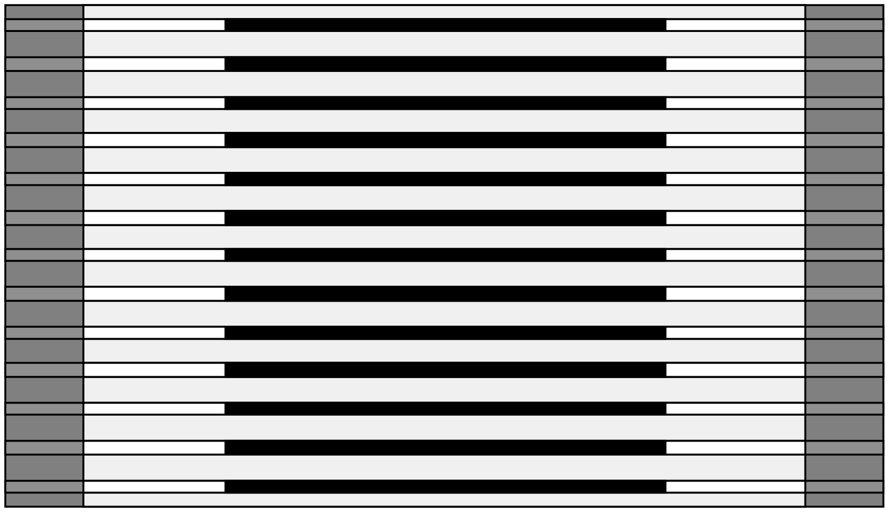
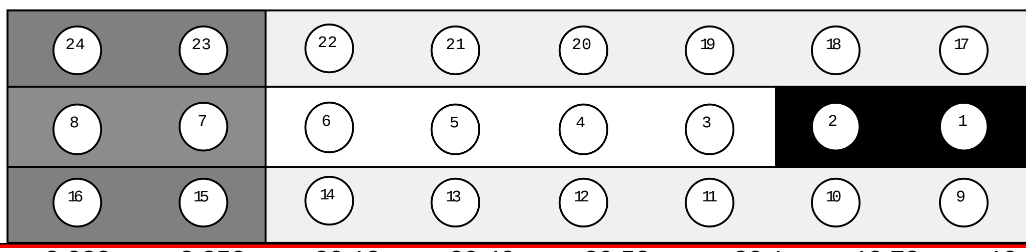


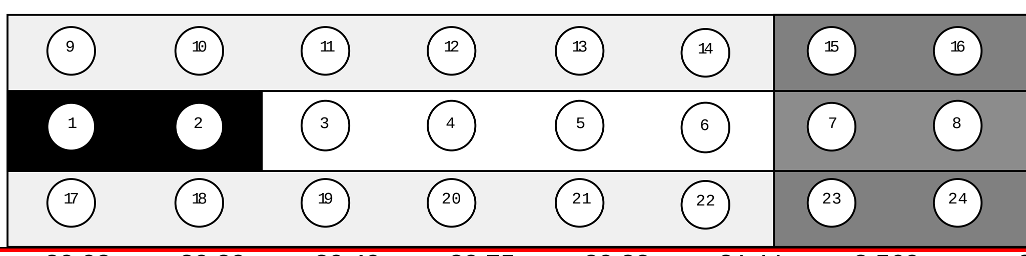
Figure II.8-2. Quantum Data "bar BLACK" Test Target

Table II.8-2. Quantum Data "bar BLACK" Test Target Measured Luminance in fL.



3.288	3.352	20.18	20.49	20.58	20.1	19.78	19.99
3.361	3.432	20.19	20.83	20.54	20.42	1.589	1.552
3.367	3.373	20.13	20.56	20.44	20.07	20.1	20.13

Left side white-to-black leading transition of black bar.



20.03	20.29	20.49	20.75	20.82	21.11	3.569	3.5
1.503	1.558	20.42	21.1	21.2	21.39	3.606	3.513
20.26	20.37	20.85	20.74	20.94	20.75	3.159	3.484

Right side black-to-white trailing transition of black bar.

II.9. Addressability

Reference: Monochrome CRT Monitor Performance, Draft Version 2.0, Section 6.1, page 67.

This monitor properly displayed all but 3 stuck pixels when operated in the native format of 1024 x 768 pixels (H x V).

Objective: Define the number of addressable pixels in the horizontal and vertical dimension; confirm that stated number of pixels is displayed.

Equipment: Programmable video signal generator.
Test pattern with pixels lit on first and last addressable rows and columns and on two diagonal lines beginning at upper left and lower right; H and V grille patterns 1-pixel-on/1-pixel-off.

Procedure: The number of addressed pixels were programmed into the Quantum Data 8701 test pattern generator for 75 Hz for monoscopic mode and 120 Hz maximum addressable for stereoscopic mode, where possible. All perimeter lines were confirmed to be visible, with no irregular jaggies on diagonals and, for monochrome monitors, no strongly visible moiré on grilles.

Data: If tests passed, number of pixels in horizontal and vertical dimension. If test fails, addressability unknown.

Table II.9-1 Addressabilities Tested

Monoscopic Mode	Stereo Mode*
1024 x 768 x 75 Hz Non-Interlaced	1024 x 768 x 85 Hz Interlaced (43 Hz per eye)

* Manufacturer states 91.1 kHz maximum scan rate, thus, 120 Hz vertical scan rate is not achievable in stereo mode. Manufacturer states a maximum vertical refresh rate of 85 Hz.

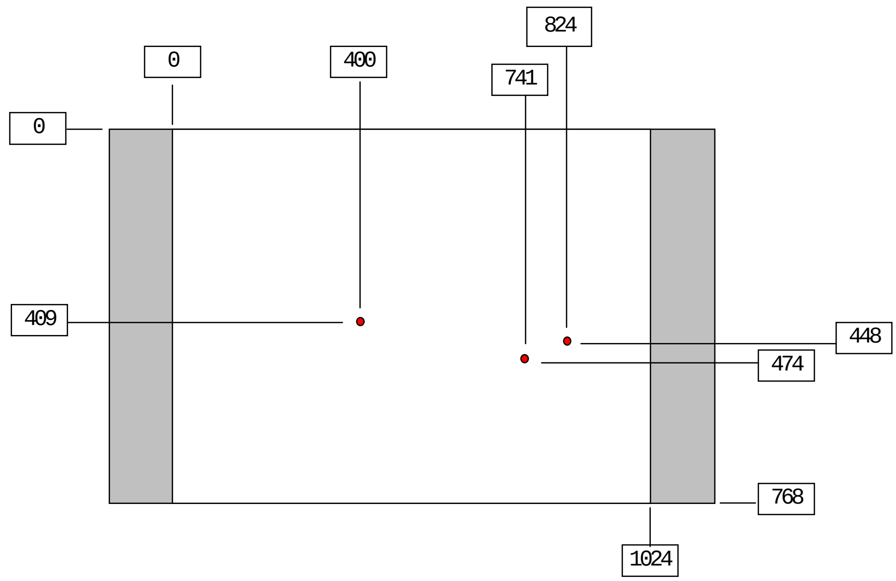


Figure II.9-1. *Inoperative Stuck Pixels (at given x,y coordinates)*

II.10. Pixel Aspect Ratio

Reference: Request for Evaluation Monitors, NIDL Pub. 0201099-091, Section 5.10, p 8.

Pixel aspect ratio is within 6.21%.

Objective: Characterize aspect ratio of pixels.

Equipment: Test target, measuring tape with at least 1/16th inch increments

Procedure: Display box of 400 x 400 pixels at input count corresponding to 50% Lmax and background of 0. Measure horizontal and vertical dimension.

Alternatively, divide number of addressable pixels by the total image size to obtain nominal pixel spacings in horizontal and vertical directions.

Data: Define pass if H= V± 6% for pixel density <100 ppi and ± 10% for pixel density > 100 ppi.

	Monoscopic Mode
Addressability (H x V)	**1024 x 768**
H x V Image Size (inches)	34.535 x 24.387
H x V Pixel Spacing (mils)	21.58 x 20.32
H x V Pixel Aspect Ratio	H = V + 6.21%

II.11. Screen Size (Viewable Active Image)

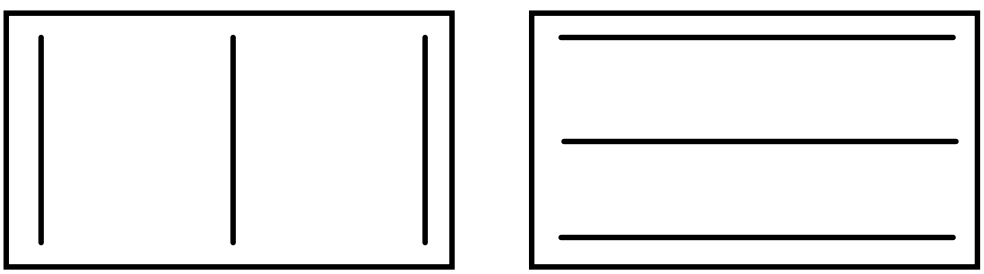
Reference: VESA Flat Panel Display Measurements Standard, Version 1.0, May 15, 1998, Section 501-1.

Image size as tested in monoscopic mode (1024 x 768) was 42.278 inches in diagonal with an aspect ratio of 4:3. Maximum viewable image size is 50 inches in diagonal and 16:9 aspect ratio.

Objective: Measure beam position on the LCD display to quantify width and height of active image size visible by the user (excludes any overscanned portion of an image).

Equipment:
- Video generator
- Spatially calibrated CCD or photodiode array optic module
- Calibrated X-Y translation stage

Test Pattern: Use the three-line grille patterns in Figure II.11-1 for vertical and horizontal lines each 1-pixel wide. Lines in test pattern are displayed at 100% L_{max} must be positioned along the top, bottom, and side edges of the addressable screen, as well as along both the vertical and horizontal centerlines (major and minor axes).



1-pixel-wide lines displayed at 100% L_{max}

Figure II.11-1 Three-line grille test patterns.

Procedure: Use diode optic module to locate center of line profiles in conjunction with calibrated X-Y translation to measure screen x,y coordinates of lines at the ends of the major and minor axes.

Data: Compute the image width defined as the average length of the horizontal lines along the top, bottom and major axis of the screen. Similarly, compute the image height defined as the average length of the vertical lines along the left side, right side, and minor axis of the screen. Compute the diagonal screen size as the square-root of the sum of the squares of the width and height.

Table II.11-1. Image Size as tested.

	Monoscopic Modes
Addressability (H x V)	**1024 x 768**
H x V Image Size (inches) Diagonal Image Size (inches)	34.535 x 24.387 42.278

II.12. Contrast Modulation and RAR

Reference: Monochrome CRT Monitor Performance, Draft Version 2.0, Section 5.2, page 57.

Contrast modulation (Cm) for 1-on/1-off grille patterns displayed at 50% Lmax exceeded Cm = 63% in Zone A of diameter 7.6 inches, and exceeded 62% for Zone A diameter of 20.7 inches (40% of image area). CM exceeded 62% for zone B. The Resolution-Addressability-Ratio (RAR) was 1.47 x 0.91 (H x V) based on measured linewidths.

Objective: Quantify contrast modulation as a function of screen position.

Equipment:
- Video generator
- Spatially calibrated CCD or photodiode array optic module
- Photometer with linearized response

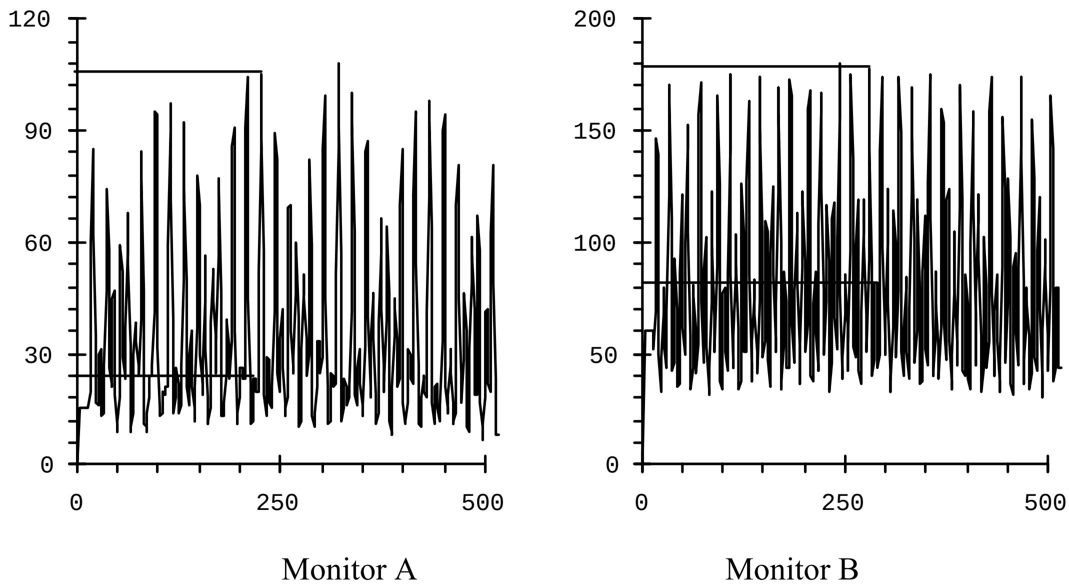
Procedure: The maximum video modulation frequency for each format 1024 x 768 was examined using horizontal and vertical grille test patterns consisting of alternating lines with 1 pixel on, 1 pixel off. Contrast modulation was measured in both horizontal and vertical directions at screen center and at eight peripheral screen positions. The measurements should be along the horizontal and vertical axes and along the diagonal from these axes. Use edge measurements no more than 10% of screen size in from border of active screen. The input signal level was set so that 1-line-on/1-line-off horizontal grille patterns produced a screen area-luminance of 25% of maximum level, Lmax.

Zone A is defined as a 24 degree subtended circle from a viewing distance of 18 inches (7.6 inch circle). Zone B is the remainder of the display. Use edge measurements no more than 10% of screen size in from border of active screen area to define Cm for Zone B (remaining area outside center circle). Determine Cm at eight points on circumference of circle by interpolating between center and display edge measurements to define Cm for Zone A. If measurements exceed the threshold, do not make any more measurements. If one or more measurements fail the threshold, make eight additional measurements at the edge (but wholly within) the defined circle.

Data: Values of vertical and horizontal Cm for Zone A and Zone B are given in Table II.12-1. The contrast modulation, Cm, is reported (the defining equation is given below) for the 1-on/1-off grille patterns. The modulation is equal to or greater than 63% in Zone A, and is equal to or greater than 62% in Zone B.

$$C_m = \frac{L_{peak} - L_{valley}}{L_{peak} + L_{valley}}$$

The sample contrast modulations shown in Figure II.12-1 for two different color CRTs are not fully realized because of the presence of moiré caused by aliasing between the image and the shadow mask. Because contrast modulation values are calculated for the maximum peak and minimum valley luminance levels as indicated in the sample data shown, they do not include the degrading effects of aliasing.



$$Cm = \frac{105 - 24}{105 + 24} = 63\% \qquad Cm = \frac{179 - 821}{179 + 821} = 37\%$$

Figure II.12-1. *Contrast modulation for sample luminance profiles (1 pixel at input level corresponding to 50% Lmax, 1 pixel at level 0 = Lmin) for monitors exhibiting moiré due to aliasing.*

Table II.12-1. Contrast Modulation

Corrected for lens flare and Zone Interpolation

Zone A = 7.6-inch diameter circle for 24-degree subtended circle at 18-inches viewing distance

	Left				Minor				Right	
	H-grille	V-grille	H-grille	V-grille	H-grille	V-grille	H-grille	V-grille	H-grille	V-grille
Top	78%	65%			79%	63%			79%	62%
			76%	63%	77%	63%	77%	63%		
Major	76%	64%	76%	63%	76%	63%	76%	63%	77%	63%
			76%	64%	77%	63%	77%	63%		
Bottom	78%	66%			78%	62%			79%	62%

Zone A = 20.7-inch diameter circle for 40% area

	Left				Minor				Right	
	H-grille	V-grille	H-grille	V-grille	H-grille	V-grille	H-grille	V-grille	H-grille	V-grille
Top	78%	65%			79%	63%			79%	62%
			77%	64%	79%	63%	78%	63%		
Major	76%	64%	76%	64%	76%	63%	77%	63%	77%	63%
			77%	65%	78%	62%	78%	63%		
Bottom	78%	66%			78%	62%			79%	62%

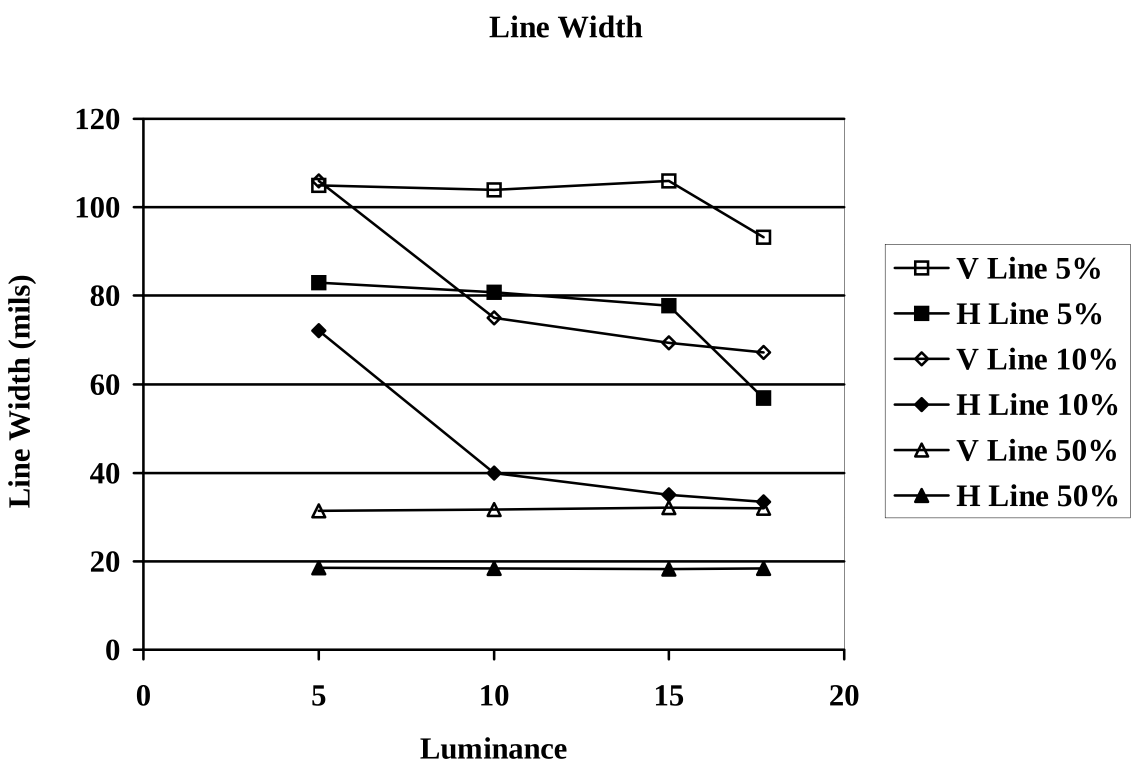


Figure II.12-2. *Linewidth at 50% intensity level measured at screen center is used to compute the Resolution-Addressability-Ratio (RAR) by dividing by the measured pixel spacing of 21.58 H x 20.32 V mils. Thus, RAR averaged over the luminance range is 1.47 H x 0.91 V.*

II.13. Pixel Density

Reference: Request for Evaluation Monitors, NIDL Pub. 0201099-091, Section 5.13, p 9.

Pixel density was 30 H x 32 V pixels per inch (ppi) as measured for a 400-pixel target.

Objective: Characterize density of image pixels

Equipment: Measuring tape with at least 1/16 inch increments

Procedure: Measure H&V dimension of active image window and divide by vertical and horizontal addressability

Data: Define horizontal and vertical pixel density in terms of pixels per inch

Table II.13-1. Pixel-Density

	Monoscopic Mode
H x V Addressability, Pixels	**1024 x 768**
H x V 400-Pixel Target Size, Inches	13.470 x 12.684
H x V Pixel Density, ppi	30 x 32

II.14. Moiré

Reference: Request for Evaluation Monitors, NIDL Pub. 0201099-091, Section 5.14, p 9.

The Pioneer PDP-502MX Plasma Display Panel shows no moiré when operated using a one-to-one pixel mapping between input signal and the native addressable pixels. As tested in 1024 x 768 mode, only 80% of the available 1280 x 768 total pixels were addressed leaving the side edges of the screen dark.

Objective: Determine lack of moiré.

Equipment Loupe with scale graduated in 0.001 inch or equivalent

Procedure Measure phosphor pitch in vertical and horizontal dimension at screen center. For aperture grille screens, vertical pitch will be 0. Define pixel size by 1/pixel density.

Data: Define value of phosphor: pixel spacing. Value <1 passes, but <0.6 preferred.

Table II.14-1. Phosphor-to-Pixel-Spacing Ratios

	Monoscopic Mode
Addressability	1024 x 768
Phosphor Trio Spacing (H x V)	21.8 x 20.5 mils
Pixel Spacing (H x V)	21.8 x 20.5 mils
Phosphor-to-Pixel-Spacing	1.0

II.15. Straightness

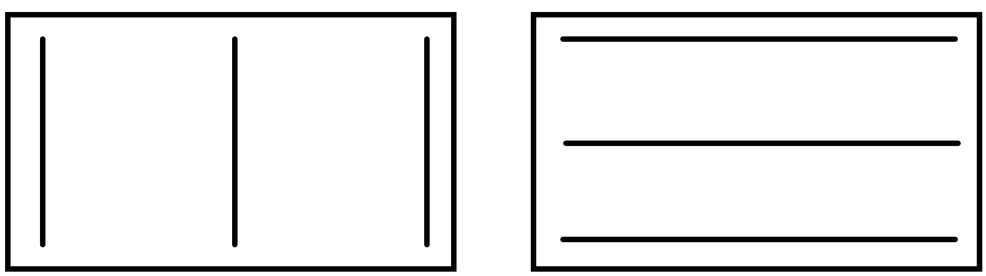
Reference: Monochrome CRT Monitor Performance, Draft Version 2.0, Section 6.1 Waviness, page 67.

Deviation from straightness did not exceed 0.05% of the total image height or width.
Note: Because this plasma panel is a fixed pixel display, the straightness measurement serves more as a test of the measurement equipment.

Objective: Measure beam position on the CRT display to quantify effects of waviness which causes nonlinearities within small areas of the display distorting nominally straight features in images, characters, and symbols.

Equipment:
- Video generator
- Spatially calibrated CCD or photodiode array optic module
- Calibrated X-Y translation stage

Test Pattern: Use the three-line grille patterns in Figure II.15-1 for vertical and horizontal lines each 1-pixel wide. Lines in test pattern are displayed at 100% L_{max} must be positioned along the top, bottom, and side edges of the addressable screen, as well as along both the vertical and horizontal centerlines (major and minor axes).



1-pixel-wide lines displayed at 100% L_{max}

Figure II.15-1 Three-line grille test patterns.

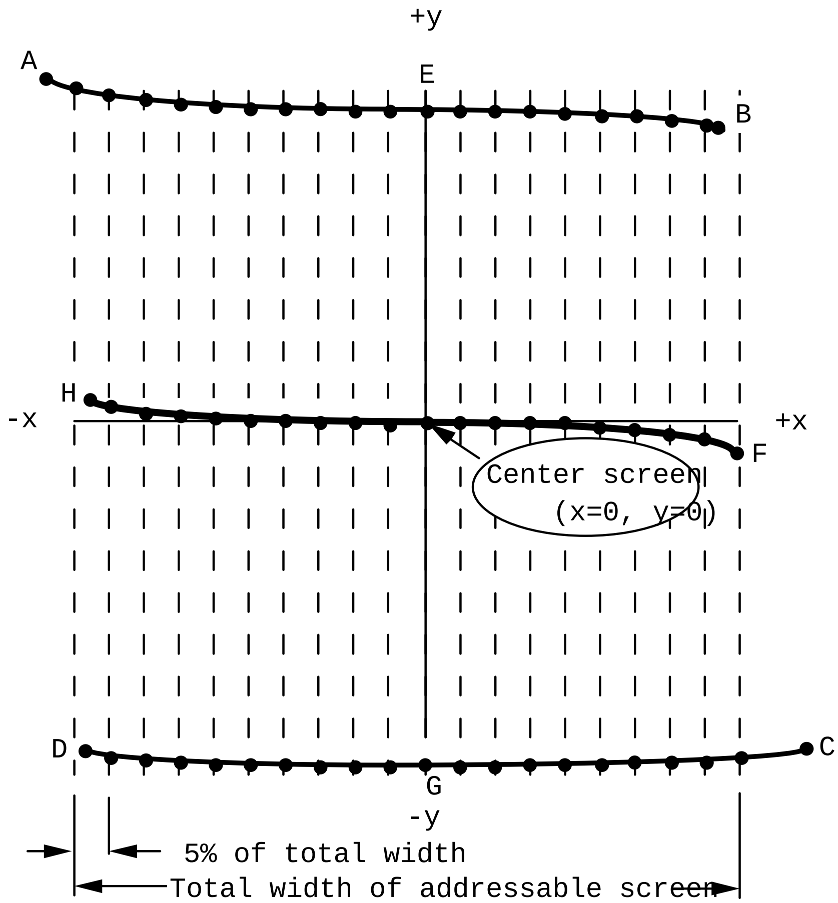


Figure II.15-2 Measurement locations for waviness along horizontal lines. Points A, B, C, D are extreme corner points of addressable screen. Points E, F, G, H are the endpoints of the axes.

Procedure: Use diode optic module to locate center of line profiles in conjunction with calibrated X-Y translation to measure screen x,y coordinates along the length of a nominally straight line. Measure x,y coordinates at 5% addressable screen intervals along the line. Position vertical lines in video to land at each of three (3) horizontal screen locations for determining waviness in the horizontal direction. Similarly, position horizontal lines in video to land at each of three (3) vertical screen locations for determining waviness in the vertical direction.

Data: Tabulate x,y positions at 5% addressable screen increments along nominally straight lines at top and bottom, major and minor axes, and left and right sides of the screen as shown in Table II.15-I. Figure II.15-3 shows the results in graphical form.

Table II.15-1. Straightness

Tabulated x,y positions at 5% addressable screen increments along nominally straight lines.

Top		Bottom		Major		Minor		Left Side		Right Side	
x	y	x	y	x	y	x	y	x	y	x	y
-17281	12231	-17296	-12153	-17295	13	6	12217	-17283	12232	17267	12230
-14400	12227	-14400	-12156	-14400	10	6	10800	-17285	10800	17265	10800
-12800	12224	-12800	-12159	-12800	7	5	9600	-17285	9600	17265	9600
-11200	12221	-11200	-12161	-11200	4	5	8400	-17285	8400	17264	8400
-9600	12218	-9600	-12164	-9600	1	4	7200	-17287	7200	17264	7200
-8000	12218	-8000	-12165	-8000	0	2	6000	-17290	6000	17262	6000
-6400	12217	-6400	-12165	-6400	0	0	4800	-17294	4800	17258	4800
-4800	12216	-4800	-12166	-4800	-1	-4	3600	-17298	3600	17256	3600
-3200	12215	-3200	-12166	-3200	0	-6	2400	-17298	2400	17256	2400
-1600	12215	-1600	-12166	-1600	0	-5	1200	-17296	1200	17258	1200
0	12215	0	-12166	0	0	-1	0	-17294	0	17260	0
1600	12216	1600	-12166	1600	0	-1	-1200	-17294	-1200	17261	-1200
3200	12217	3200	-12165	3200	1	0	-2400	-17294	-2400	17261	-2400
4800	12218	4800	-12164	4800	1	0	-3600	-17294	-3600	17261	-3600
6400	12219	6400	-12163	6400	2	-1	-4800	-17295	-4800	17261	-4800
8000	12220	8000	-12161	8000	4	-2	-6000	-17296	-6000	17260	-6000
9600	12222	9600	-12160	9600	6	-3	-7200	-17297	-7200	17260	-7200
11200	12224	11200	-12158	11200	8	-1	-8400	-17296	-8400	17262	-8400
12800	12226	12800	-12156	12800	9	0	-9600	-17294	-9600	17265	-9600
14400	12227	14400	-12156	14400	10	1	-10800	-17294	-10800	17265	-10800
17268	12230	17204	-12153	17261	12	0	-12170	-17295	-12156	17264	-12157

1024 x 768

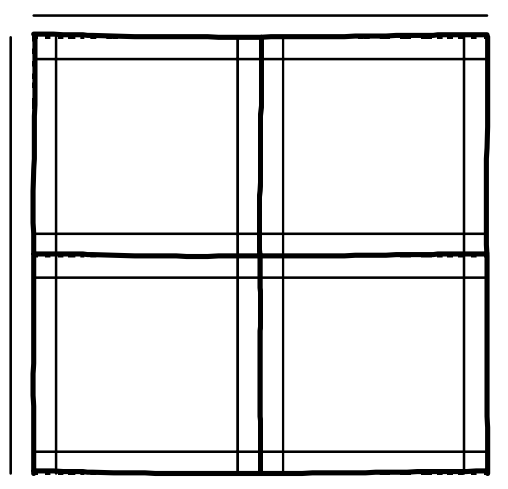


Figure II.15-3 Waviness of Pioneer PDP-502MX Plasma Display Panel in 1024 x 768 mode. Departures from straight lines are exaggerated on a 10X scale. Error bars are +/- 0.5% of total screen size.

II.16. Refresh Rate

Reference: Request for Evaluation Monitors, NIDL Pub. 0201099-091, Section 5.16, p 9.

Vertical refresh rate for 1024 x 768 format was set to 75 Hz for monoscopic mode, and limited to 43 Hz per eye for stereo mode. The PDP panel cannot achieve the necessary 120 Hz refresh rate required to achieve 60 Hz per eye for stereo.

Objective: Define vertical and horizontal refresh rates.

Equipment: Programmable video signal generator.

Procedure: The refresh rates were programmed into the Quantum Data 8701 test pattern generator for 72 Hz minimum for monoscopic mode and 120 Hz minimum for stereoscopic mode, where achievable.

Data: Report refresh rates in Hz.

Table II.16-1 Refresh Rates as Tested

	Monoscopic Mode	**Stereo Mode**
Addressability	1024 x 768	1024 x 768 Interlaced 1024 x 384 per eye
Vertical Scan Horizontal Scan	75 Hz 63.98 kHz	43 Hz per eye * 91.1 kHz

* Manufacturer states 91.1 kHz maximum scan rate, thus, 120 Hz vertical scan rate is not achievable in stereo mode. Manufacturer states a maximum vertical refresh rate of 85 Hz.

II.17. Extinction Ratio

Reference: Request for Evaluation Monitors, NIDL Pub. 0201099-091, Section 5.17, p10.

Stereo extinction ratio averaged 1.6 to 1 (1.5 left, 1.6 right) at screen center. Luminance of white varied by up to 8.0% across the screen. Chromaticity variations of white were less than 0.007 delta u'v' units. Dynamic Range is 20.3 dB with 2.26 fL Lmax measured through the stereo viewing system.

Objective: Measure stereo extinction ratio

Equipment: Two "stereo" pairs with full addressability. One pair has left center at command level of 255 (or Cmax) and right center at 0. The other pair has right center at command level of 255 (or Cmax) and left center at 0.

Stereoscopic-mode measurements were made using commercially available wireless CrystalEyes active LC shutter glasses from StereoGraphics Corporation.

Procedure: If possible, calibrate monitor to 0.1 fL Lmin and 35 fL Lmax (no ambient). Measure ratio of Lmax to Lmin on both left and right side images through the stereo system.

Data: Extinction ratio (left) = L (left,on, white/black)/left,off, black/white)

L(left,on, white/black) ~ trans(left,on)*trans(stereo)*L(max)*Duty(left)
+ trans(left,off)*trans (stereo)*L(min)*Duty (right)
Use left,off/right,on to perform this measurement

Extinction ratio (right) = L (right,on,white/black)/right,off, black/white)

L(right,on, white/black) ~ trans(right,on)*trans(stereo)*L(max)*Duty(right)
+ trans(right,off)*trans (stereo)*L(min)*Duty (left)
Use left,on/right,off to perform this measurement

Stereo extinction ratio is average of left and right ratios defined above.

Table II.17-1. Luminance and Chromaticity of White (Stereoscopic Mode)

Lmin, Average Left, Right, center	0.021 fL
Lmax, Average Left, Right, center	2.26 fL
Dynamic Range, center	20.3 dB
Uniformity, Luminance	8.0 %
Uniformity, Chromaticity	0.007 u'v'

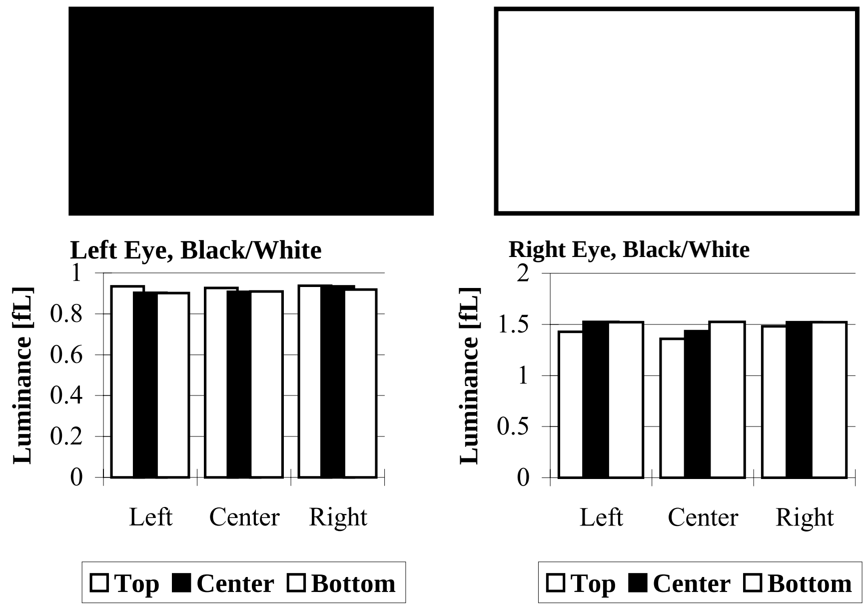


Fig.II.17-1. Spatial Uniformity of luminance in stereo mode when displaying black to the left eye while displaying white to the right eye.

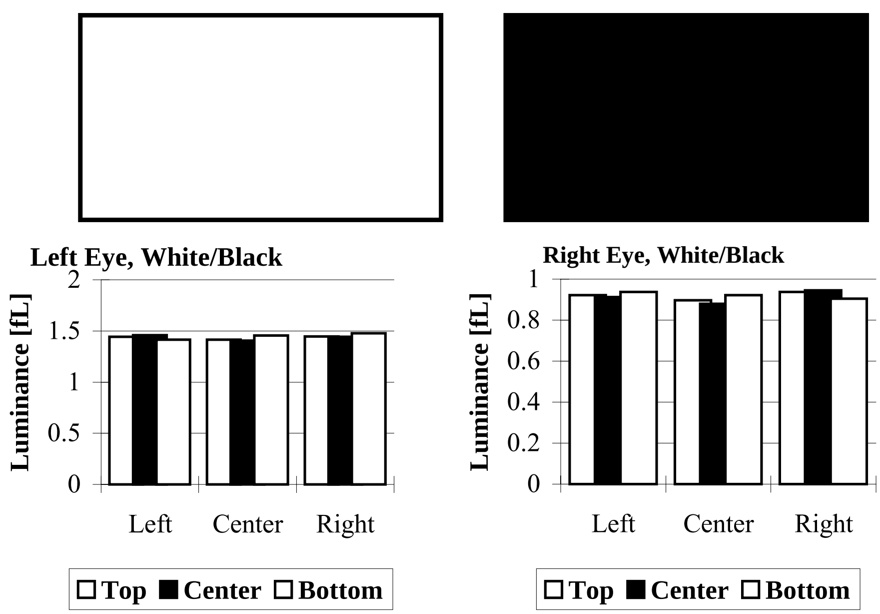


Fig.II.17-2. Spatial Uniformity of luminance in stereo mode when displaying white to the left eye while displaying black to the right eye.

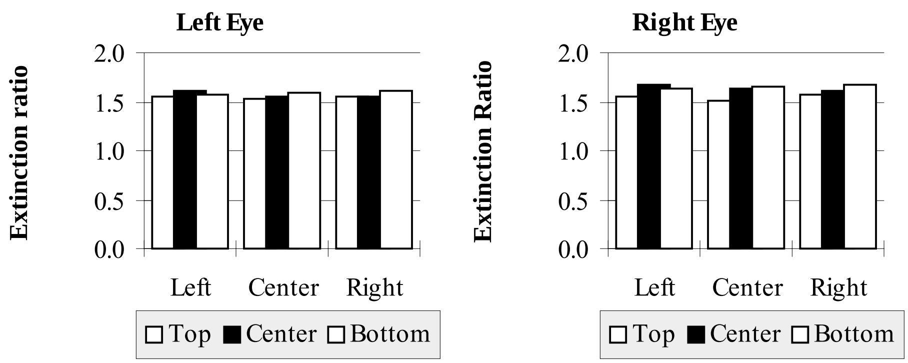


Fig.II.17-3. Spatial Uniformity of extinction ratio in stereo mode.

Fig.II.17-4 Spatial uniformity of chromaticity of white in stereo mode.

II.18. Linearity

Reference: Monochrome CRT Monitor Performance, Draft Version 2.0, Section 6.2, page 73.

The maximum nonlinearity of the displayed pixels was measured to be 0.04% of full screen. Note: Because this plasma panel is a fixed pixel display, the linearity measurement serves more as a test of the measurement equipment.

Objective: Measure the relation between the actual position of a pixel on the screen and the commanded position to quantify effects of raster nonlinearity. Nonlinearity of scan degrades the preservation of scale in images across the display.

Equipment:
- Video generator
- Spatially calibrated CCD or photodiode array optic module
- Calibrated X-Y translation stage

Test Pattern: Use grille patterns of single-pixel horizontal lines and single-pixel vertical lines displayed at 100% L_{max}. Lines are equally spaced in addressable pixels. Spacing must be constant and equal to approximately 5% screen width and height to the nearest addressable pixel as shown in Figure II.18-1.

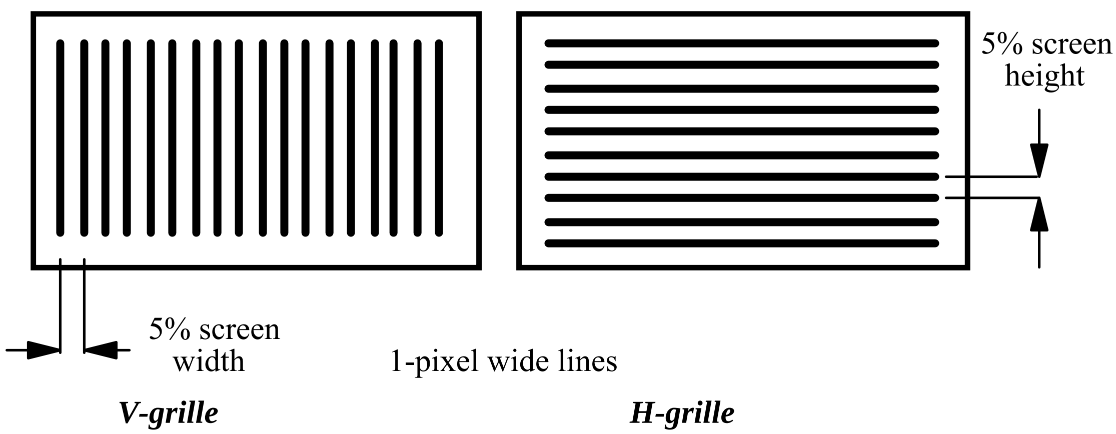


Figure II.18-1. *Grille patterns for measuring linearity*

Procedure: The linearity of the raster scan is determined by measuring the positions of lines on the screen. Vertical lines are measured for the horizontal scan, and horizontal lines for the vertical scan. Lines are commanded to 100% Lmax and are equally spaced in the time domain by pixel indexing on the video test pattern. Use optic module to locate center of line profiles in conjunction with x,y-translation stage to measure screen x,y coordinates of points where video pattern vertical lines intersect horizontal centerline of screen and where horizontal lines intersect vertical centerline of the CRT screen as shown in Figure II.18-2.

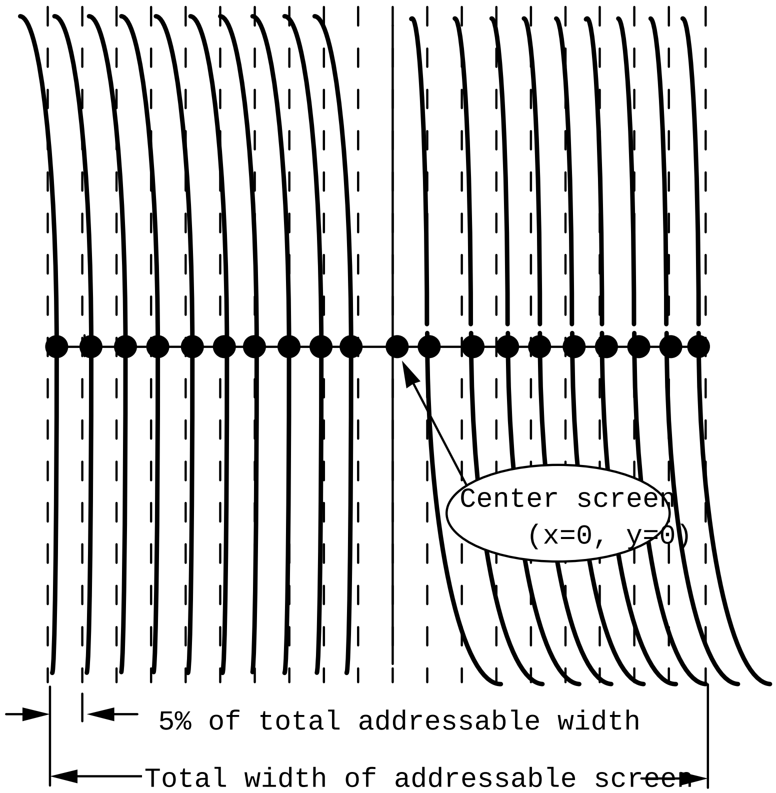


Figure II.18-2. *Measurement locations for horizontal linearity along the major axis of the display. Equal pixel spacings between vertical lines in the grille pattern are indicated by the dotted lines. The number of pixels per space is nominally equivalent to 5% of the addressable screen size.*

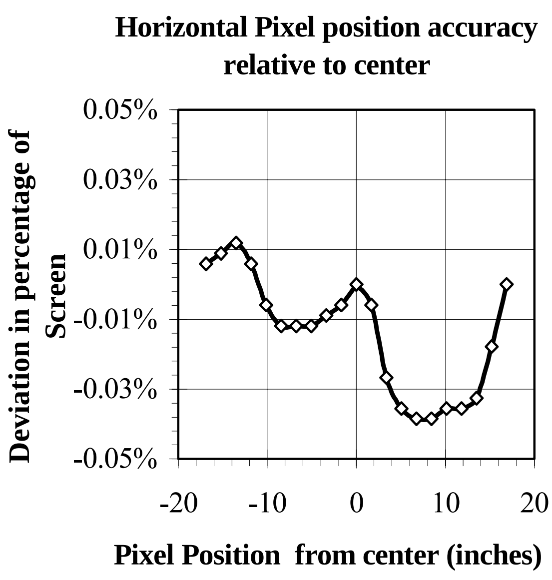
Data: Tabulate x, y positions of equally spaced lines (nominally 5% addressable screen apart) along major (horizontal centerline) and minor (vertical centerline) axes of the raster. If both scans were truly linear, the differences in the positions of adjacent lines would be a constant. The departures of these differences from constancy impact the absolute position of each pixel on the screen and are, then, the nonlinearity. The degree of nonlinearity may be different between left and right and between top and bottom. The maximum horizontal and vertical nonlinearities (referred to full screen size) are listed in table II.18-1. The complete measured data are listed in table II.18-2 and shown graphically in Figures II.18-3.

Table II.18-1. Maximum Horizontal and Vertical Nonlinearities

Format	Left Side	Right Side	Top	Bottom
1024 x 768	0.01%	0.04%	0.04%	0.04%

Table II.18-2. Horizontal and Vertical Nonlinearities Data

Vertical Lines x-Position (mils)		Horizontal lines y-Position (mils)	
Left Side	Right Side	Top	Bottom
-16888	16890	12089	-12071
-15198	15195	10876	-10862
-13508	13501	9668	-9654
-11821	11811	8461	-8447
-10136	10122	7256	-7238
-8449	8432	6048	-6033
-6760	6743	4839	-4825
-5071	5055	3630	-3617
-3381	3369	2418	-2412
-1691	1687	1208	-1208
0	0	0	0



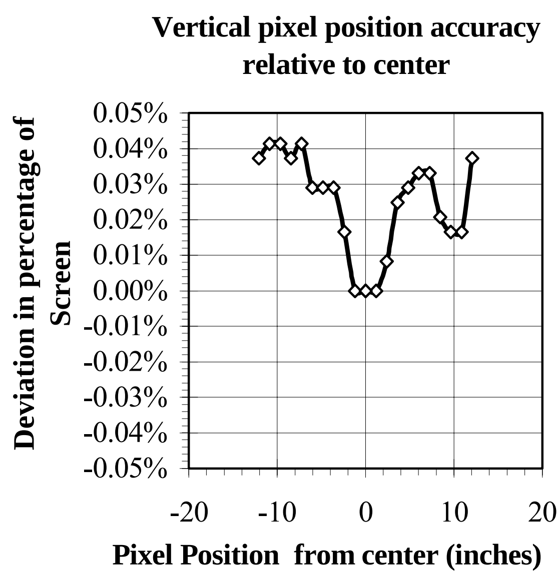


Figure. II.18-3 Horizontal and Vertical Linearity Characteristics.

II.19. Jitter/Swim/Drift

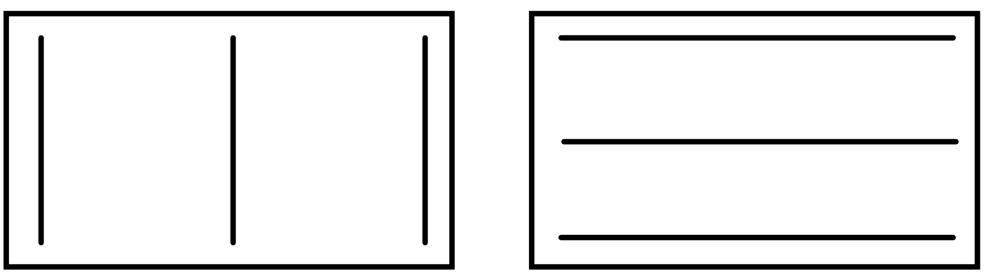
Reference: Monochrome CRT Monitor Performance, Draft Version 2.0 Section 6.4, p80.

Maximum jitter and swim/drift was 0.74 mils and 0.65 mils, respectively.

Objective: Measure amplitude and frequency of variations in beam spot position of the CRT display. Quantify the effects of perceptible time varying raster distortions: jitter, swim, and drift. The perceptibility of changes in the position of an image depends upon the amplitude and frequency of the motions, which can be caused by imprecise control electronics or external magnetic fields.

Equipment:
- Video generator
- Spatially calibrated CCD or photodiode array optic module
- Calibrated X-Y translation stage

Test Pattern: Use the three-line grille patterns in Figure II.19-1 for vertical and horizontal lines each 1-pixel wide. Lines in test pattern must be positioned along the top, bottom, and side edges of the addressable screen, as well as along both the vertical and horizontal centerlines (major and minor axes).



V-grille for measuring horizontal motion, H-grille for measuring vertical motion

1-pixel wide lines

Three-line grille test patterns.
Figure II.19-1

Procedure: With the monitor set up for intended scanning rates, measure vertical and horizontal line jitter (0.01 to 2 seconds), swim (2 to 60 seconds) and drift (over 60 seconds) over a 2.5 minute duration as displayed using grille video test patterns. Generate a histogram of raster variance with time. The measurement interval must be equal to a single field period.

Optionally, for multi-sync monitors measure jitter over the specified range of scanning rates. Some monitors running vertical scan rates other than AC line frequency may exhibit increased jitter.

Measure and report instrumentation motion by viewing Ronchi ruling or illuminated razor edge mounted to the top of the display. It may be necessary to mount both the optics and the monitor on a vibration-damped surface to reduce vibrations.

Data: Tabulate motion as a function of time in x-direction at top-left corner screen location. Repeat for variance in y-direction. Tabulate maximum motions (in mils) with display input count level corresponding to L_{max} for jitter (0.01 to 2 seconds), swim (2 to 60 seconds) and drift (over 60 seconds) over a 2.5 minute duration. The data are presented in Table II.19-1. Both the monitor and the Microvision equipment sit on a vibration-damped aluminum-slab measurement bench. The motion of the test bench was a factor of 10 times smaller than the CRT raster motion.

Table II.19-1. Jitter/Swim/Drift

Time scales: Jitter 2 sec., Swim 10 sec., and Drift 60 sec.

1024 x 768 x 75hz

		H-lines	V-lines	
10D corner	Max Motions			
	Jitter	0.874	1.75	
	Swim	0.893	1.78	
	Drift	0.901	1.78	
Black Tape	Max Motions			
	Jitter	0.538	1.01	
	Swim	0.587	1.13	
	Drift	0.587	1.15	
Less Tape Motion				maximums
	Jitter	0.34	0.74	0.74
	Swim	0.31	0.65	0.65
	Drift	0.31	0.63	0.63

II.20. Warm-up Period

Reference: Request for Evaluation Monitors, NIDL Pub. 0201099-091, Section 5.20, p. 10.

Less than a minute warm-up was necessary for luminance to be stable to within 10% of Lmin = 0.234 fL

Objective: Define warm-up period

Equipment: Photometer, test target (full screen 0 count)

Procedure: Turn monitor off for three-hour period. Turn monitor on and measure center of screen luminance (Lmin as defined in Dynamic range measurement) at 1-minute intervals for first five minutes and five-minute intervals thereafter. Discontinue when three successive measurements are ± 10% of Lmin.

Data: Pass if Lmin within ± 50% in 30 minutes and ±10% in 60 minutes.

The luminance of the screen (commanded to the minimum input level, 0 for Lmin) was monitored for 120 minutes after a cold start. Measurements were taken every minute. Figure II.20-1 shows the data for 1024 x 768 format in graphical form. The luminance remains very stable after 53 minutes.

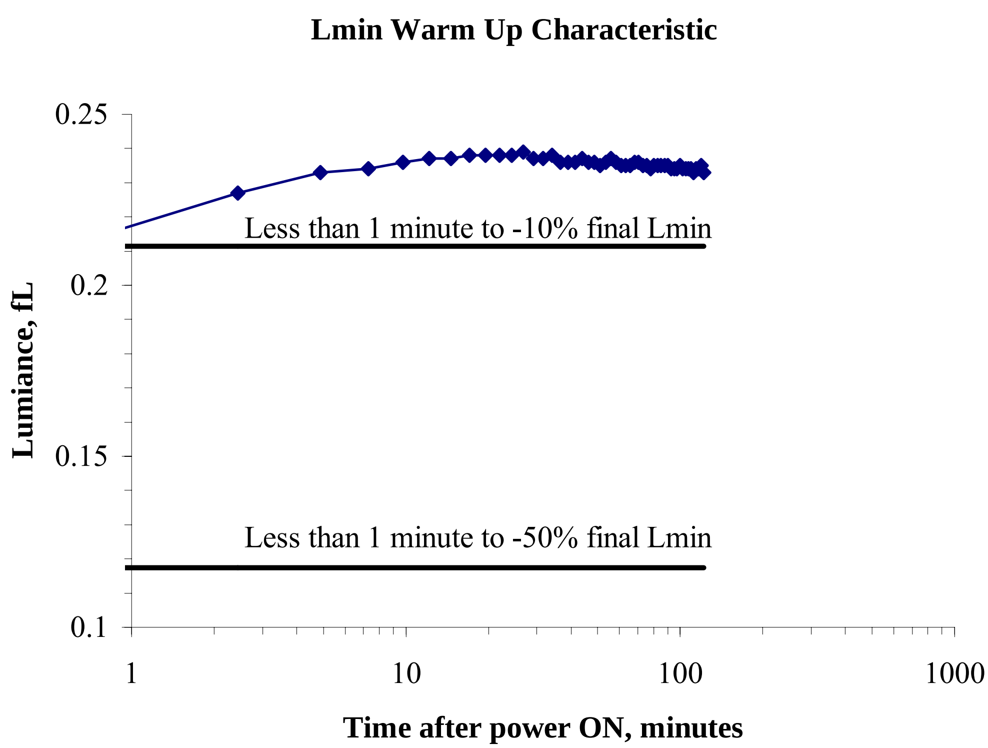


Figure II.20.1. Luminance (fL) as a function of time (in minutes) from a cold start with an input count of 0. (Note suppressed zero on luminance scale).